

Engineering Design File

Geochemical Study for Perched Water Source Identification at INTEC

**Idaho
Cleanup
Project**

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<p>5. Summary: This Engineering Design File (EDF) report summarizes the results of a geochemical study to evaluate water sources responsible for perched water that exists beneath the northern part of the Idaho Nuclear Technology and Engineering Center (INTEC) facility. The geochemical study consisted of a 1-year sampling program intended to assess the influence of various potential recharge sources on the perched water beneath INTEC. Identification of water recharge sources is important in reducing the flux of contaminants toward the aquifer beneath INTEC, as required by the Comprehensive Environmental Response, Compensation, and Liability Act as part of the remedy for Operable Unit 3-13 Group 4, Perched Water.</p> <p>The water quality and stable isotope data indicate that the perched water beneath the northern part of INTEC originates from several different sources. These recharge sources include intentional discharge of water to unlined ditches, leakage from underground pipelines, and infiltration of rain and snowmelt. Precipitation by itself does not appear to account for all of the observed perched water.</p> <p>The geochemical data indicate that a combination of water leaks and intentional discharges within the northern portion of INTEC are the primary sources of perched water recharge beneath the facility. Infiltration of rain and snowmelt also contribute to perched water recharge, but the magnitude of precipitation infiltration varies significantly from year to year. Although the Big Lost River has not flowed since 2000, infiltration of water into the riverbed periodically results in rapid recharge of perched water. These recharge sources contribute to the continued migration of radionuclides and other contaminants from contaminated surficial soils and perched water toward the aquifer.</p> <p>Based on nitrogen and oxygen isotope ratios, the elevated nitrate concentrations currently observed in the aquifer beneath INTEC appear to result from downward migration of nitrate from vadose zone and perched water sources near the tank farm. The elevated nitrate in the perched water appears to be predominately derived from a manufactured source, such as nitric acid, not from nitrogen associated with the treated sewage effluent formerly discharged at the sewage treatment plant. Treated wastewater effluent previously discharged to the former infiltration trenches at the sewage treatment plant does not appear to have significantly impacted water quality in the aquifer beneath INTEC.</p>				
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Geochemical Study for Perched Water Source Identification at INTEC

1. INTRODUCTION

The Idaho National Laboratory (INL) is divided into ten waste area groups (WAGs) to better manage environmental operations mandated under a Federal Facility Agreement and Consent Order (U.S. Department of Energy Idaho Operations Office [DOE-ID] 1991). The Idaho Nuclear Technology and Engineering Center (INTEC), formerly the Idaho Chemical Processing Plant (CPP), is designated as WAG 3. Operable Unit (OU) 3-13 encompasses the entire INTEC facility. Ninety-nine release sites were identified in the OU 3-13 Remedial Investigation/Feasibility Study, of which 46 were shown to have a potential risk to human health or the environment (DOE-ID 1997). The 46 sites were divided into seven groups based on similar media, contaminants of concern, accessibility, or geographic proximity. The seven groups identified in the Record of Decision (ROD) include (1) Tank Farm Soils, (2) Soils Under Buildings and Structures, (3) Other Surface Soils, (4) Perched Water, (5) Snake River Plain Aquifer (SRPA), (6) Buried Gas Cylinders, and (7) SFE-20 Hot Waste Tank System. The OU 3-13 ROD (DOE-ID 1999) identifies remedial design/remedial action objectives for each of the seven groups. This engineering design file (EDF) supports Group 4, Perched Water. The final ROD for OU 3-13, signed in October 1999 (DOE-ID 1999), presents the selected remedial actions for the seven groups, including Group 4 perched water.

Group 4, Perched Water, consists of variably saturated perched water zones above the regional SRPA. Perched water has been contaminated by leaching and downward transport of contaminants, primarily radionuclides, from the overlying surface soils and from two instances in which the former INTEC injection well (CPP-23) collapsed and service wastewater was released to the deep perched zones. The service wastewater discharged into the injection well comprised plant cooling water, demineralizer and boiler blowdown water, and Process Equipment Waste Evaporator (PEWE) condensates. With the startup of the Liquid Effluent Treatment and Disposal (LET&D) facility in the early 1990s, releases of radionuclides to the service waste stream were essentially eliminated.

1.1 Project Purpose

This EDF summarizes the results of a geochemical study to determine water sources responsible for recharge of the perched water bodies beneath the northern part of the INTEC facility. The Monitoring Well and Tracer Study (MWTS) report (DOE-ID 2003a) recommended that a geochemical investigation be performed to “fingerprint” various water sources at INTEC and determine the sources of water in the perched water monitoring wells. An additional goal of the geochemical study was to identify the water sources that contribute to contaminant migration and, if possible, provide recommendations to reduce or eliminate those water sources. If the primary water sources could be eliminated, then the transport and migration of contamination from vadose zone to the aquifer could be slowed significantly or stopped.

The geochemical study was designed to help meet the following remediation goals set forth in the OU 3-13 ROD for the perched water: (1) “reduce recharge to the perched water” and (2) “minimize migration of contaminants to the SRPA, so that SRPA groundwater outside of the current INTEC security fence meets the applicable State of Idaho groundwater standards by the year 2095” (DOE-ID 1999).

1.2 Regulatory Background

The OU 3-13 ROD identified remedies for the seven groupings with shared characteristics or common contaminant sources at INTEC, including Perched Water (Group 4). The remedial actions chosen in the ROD are in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980 as amended by the Superfund Amendments and Reauthorization Act of CERCLA of 1986. In addition, the remedies comply with the National Oil and Hazardous Substances Pollution Contingency Plan (EPA 1990) and are intended to satisfy the requirements of the Federal Facility Agreement and Consent Order. DOE-Idaho is the lead agency for remedy decisions. The Environmental Protection Agency (EPA) Region 10 and the Idaho Department of Environmental Quality (DEQ) approve these decisions.

2. SITE DESCRIPTION AND BACKGROUND

The following sections describe the INL, the INTEC facility, and summarize the INTEC Water System Engineering Study and the sampling conducted in support of the geochemical study. The INTEC Water System Engineering Study and geochemical study were conducted to evaluate sources of water for the perched water bodies and were recommendations in the MWTS report (DOE-ID 2003a).

2.1 INL Background

The INL is a U.S. Government-owned facility managed by the U.S. Department of Energy (DOE). The eastern boundary of the INL is located 52 km (32 mi) west of Idaho Falls, Idaho. The INL Site occupies approximately 2,305 km² (890 mi²) of the northwestern portion of the Eastern Snake River Plain in southeast Idaho. The INTEC facility covers an area of approximately 0.39 km² (0.15 mi²), and is located approximately 72.5 km (45 mi) from Idaho Falls, in the south-central area of the INL as shown in Figure 2-1.

2.2 INTEC Background

In 1951, a spent nuclear fuel (SNF) reprocessing facility called the Idaho Chemical Processing Plant (ICPP) was built in Idaho on a government reservation known as the National Reactor Testing Station (NRTS). Today, the CPP is known as the Idaho Nuclear Technology and Engineering Center (INTEC), and the NRTS is known as the Idaho National Laboratory (INL). The primary missions of the ICPP were nuclear research and storage and reprocessing of SNF for the Navy. During its operational history, the CPP reprocessed more than 100 types of SNF, each in a separate campaign. The spent fuel came from navy ships, reactors on the NRTS, commercial reactors, and university and test reactors located throughout the world.

The CPP was a heavy industrial plant that generated large amounts of radioactive waste. The Atomic Energy Commission's general waste management philosophy during the Cold War was to retain the waste that had high levels of radioactivity and to dilute and disperse the waste that had low levels of radioactivity to the air, water, or soil. At the CPP, highly radioactive liquid wastes were stored in underground stainless-steel tanks at the tank farm. Although the tank farm tanks have not leaked, piping to the tanks has leaked and contaminated the soil. Since 1963, much of the radioactive liquid waste has been converted into a solid granular form, known as calcine, to reduce its volume and mobility.

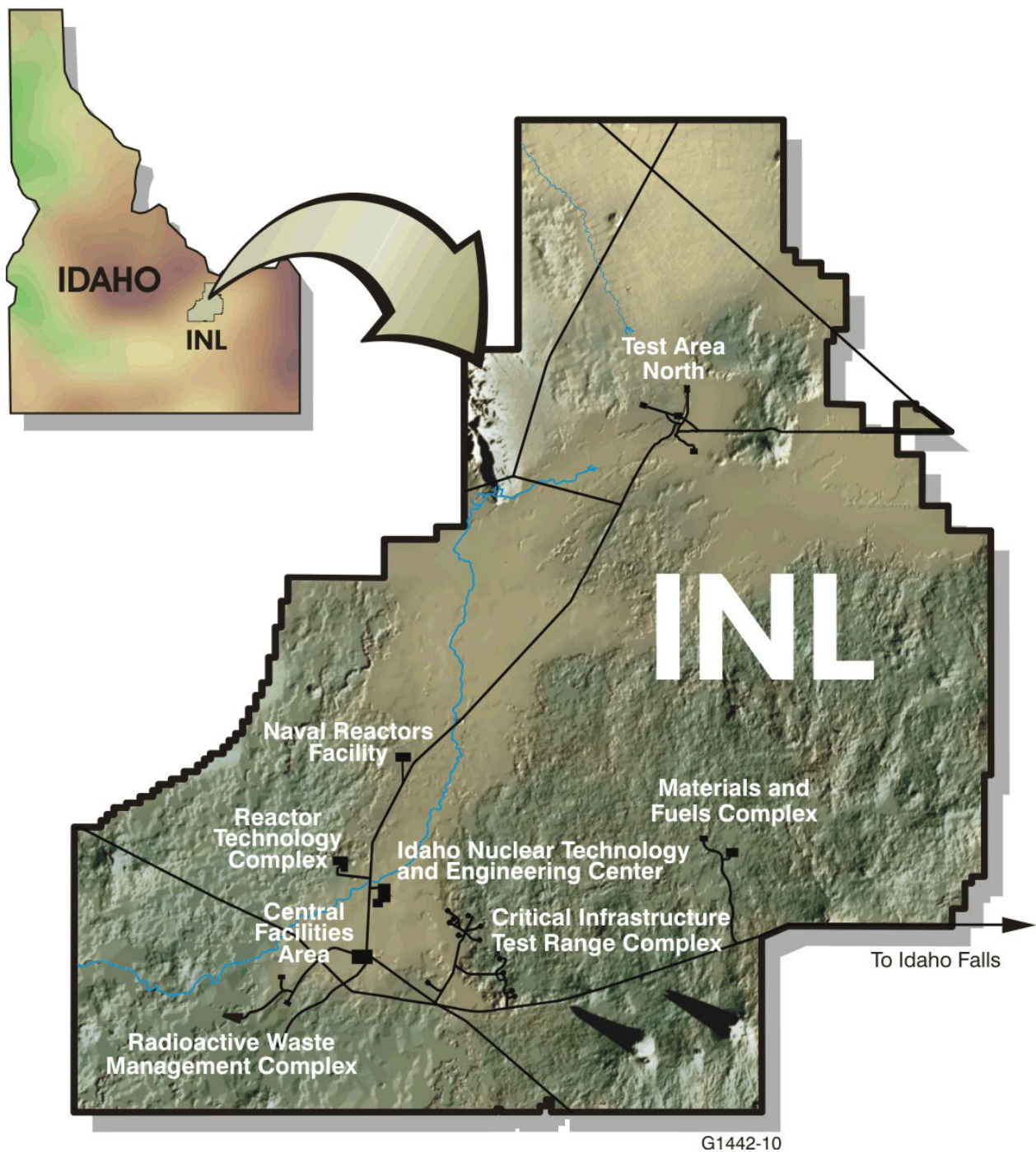


Figure 2-1. Map of the INL showing the location of INTEC.

With the end of the Cold War, the U.S. Government made a decision in 1992 to discontinue SNF reprocessing at the CPP, and the priority shifted to clean up the legacy wastes from the Cold War. As a result, DOE redirected the plant's mission to include: (1) receipt and temporary storage of SNF and other radioactive waste for future disposition, (2) management of current and past wastes, and (3) performance of remedial actions. Subsequently, the facility was renamed INTEC to reflect its changed mission.

Groundwater and perched water became contaminated as a result of past operations at INTEC. Contaminant sources at INTEC include the former injection well that previously received low-level radioactive aqueous waste from plant processes (service waste), the former percolation ponds, and downward percolation of water through contaminated soil at the INTEC tank farm, where high-level liquid waste historically has been stored. The nature and extent of perched water and groundwater contamination at INTEC have been investigated for nearly 50 years, and the principal contaminants of concern (COCs) are radionuclides, including tritium, Sr-90, Tc-99, and I-129.

The data collected during the Phase I MWTS report confirmed that the northern and southern shallow perched water systems at INTEC are separate hydrologic systems with different water sources (DOE-ID 2003a). Perched water is also differentiated by depth including a shallow perched water zone (approximately 33.5 to 42.7 m [110 to 140 ft] depth) and a deep perched water zone (approximately 115.8 m [380 ft] depth). The southern perched water zone was due primarily to the percolation ponds located at the southern end of INTEC. The ponds received all plant service wastewater from the time that the injection well was discontinued in 1984, until the new percolation ponds were placed into service in August 2002. The northern perched water system appears more complex than the southern perched system with several sources of water contributing to the creation of the northern perched water systems. Based on water-level analysis conducted for the MWTS (DOE-ID 2003a), recharge from the Big Lost River is very likely when it flows, but the amount of recharge is difficult to quantify.

2.3 Summary of INTEC Water System Engineering Study

A Water System Engineering Study (WSES) was performed in 2003 and 2004 (DOE/ID, 2003c). This study attempted to accomplish two goals: (1) determine if an appreciable quantity of water is leaking or is being discharged from plant water systems that may contribute to perched water recharge and (2) provide recommendations for the quantification, identification, and minimization or elimination of facility-contributing factors. The findings of the INTEC Water System Engineering Study are summarized below.

- Data gaps identified during the water system engineering study affect the ability to monitor system discharges and to develop a defensible water balance. There is an overall lack of reliable data to estimate losses from the fire/raw water and potable water systems at INTEC.
- As of December 2003, when the INTEC Water System Engineering Study was published, there were five buildings at INTEC that use septic tanks. These buildings were listed as low load buildings in the 1993 water inventory study (WINCO 1993, 1994). Figure 2-2 depicts the buildings that use septic tanks within the fenced area of INTEC.
- Fire hydrants within INTEC are tested yearly, in accordance with National Fire Protection Association (NFPA) requirements. Testing is typically conducted in August. The quantity of water used for testing the fire hydrants is not currently measured. During weekly testing, the fire water discharge is approximately 900 gal over a 30-minute period once a week, and approximately 54,000 gal over a 3-day period during fire hydrant flushing every August. The estimated volume of water discharged from the fire hydrants during yearly testing is 46,000 gal (Fluke 2003). These discharges are either to the ground or are directed to storm water drainages.

■ Lawns ■ Puddle ■ Septic Building/System ■ Fire Pump Cooling Discharge ★ Condensate Discharge

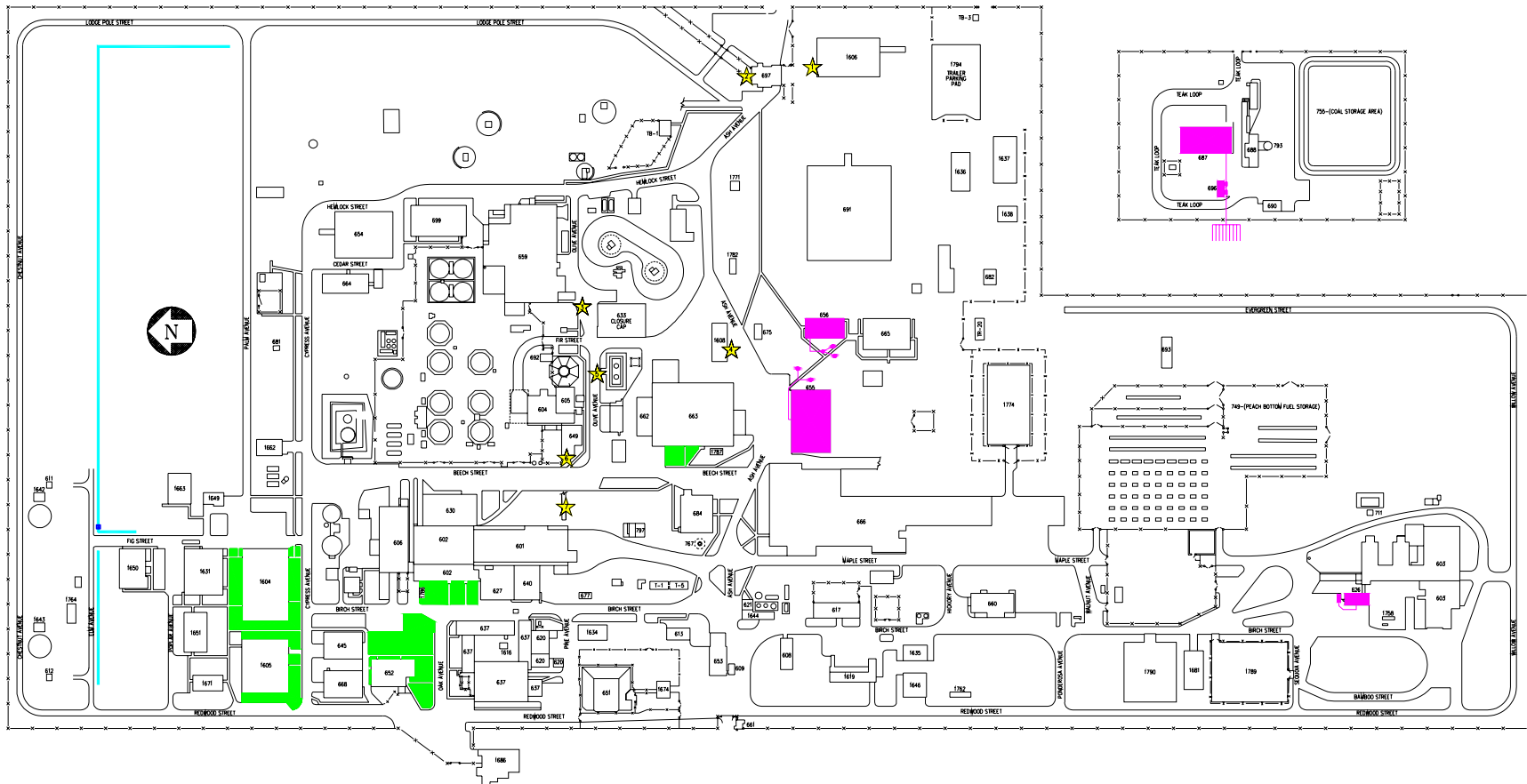


Figure 2-2. Selected water discharge locations at INTEC.

- As noted in the WSES report (DOE/ID, 2003c), a steady stream of water was noted coming from the pipe in the ditch at the corner of Elm Avenue and Fig Street (Figure 2-2). This discovery was made prior to the fire hydrant flushing operations noted earlier. Investigation of the system indicates the leak-off from the packing glands of the diesel-driven firewater pumps is the most likely source of this flow. The flow rate is estimated at 1/2 to 1 gpm. This is believed to be a constant stream due to the presence of algae growth and water bugs in the puddle formed by this stream. Figure 2-2 shows the location of the puddle created from the steady stream within INTEC. This indicates a release to ground surface of about 263,000 to 526,000 gal of water per year, which could contribute to perched water recharge in the northern part of INTEC.
- From April through October, several lawns are maintained at INTEC. Currently, all landscaping water is provided by the firewater system with an estimated flow of 5,200 gal per day. These lawns are watered at night to limit losses to evaporation. Approximately 1.5 acres are maintained as lawns. The areas of currently maintained lawns are shown in Figure 2-2.
- SNF storage basins are located in Buildings CPP-603 and CPP-666. These basins are periodically recharged with water to maintain their water levels within the desirable range. Currently, water is being supplied from the firewater system to the CPP-603 basins to provide makeup for natural evaporative losses. The quantity of this water is not reported.
- During the course of normal steam system operations, steam is released to the atmosphere as both steam and condensate due to blowdown. The bulk of this water is assumed to be released to the atmosphere as water vapor and is not a consideration with respect to perched water bodies beneath INTEC, but could affect the system water balance accuracy. Several locations were identified in the steam condensate system where unmonitored condensate water is allowed to go to the ground. Phase II of the water system engineering study will include a physical measurement to better estimate the discharges as applicable. While discharges from the steam condensate system can be estimated, the overall losses to the atmosphere and to any possible leaks cannot currently be quantified.
- An underground 50,000-gal brine storage pit (VES-UTI-625) is associated with the treated water system, designated as CPP-736. Currently, no means exist to quantify possible leakage from the brine pit or associated piping. The brine pit contains a concentrated sodium chloride solution; thus, the possibility for tank degradation exists.

2.4 Description of Geochemical Study Sampling Activities

The geochemical study was a 1-year sampling program designed to monitor the influence from various potential sources of perched water (DOE-ID 2003b). The geochemical study was designed to characterize the various water sources (sewage lagoons, drinking water supply, steam discharge, precipitation, and fire water/raw water) in terms of major cation and anion chemistry and oxygen and hydrogen isotope ratios and to identify their contribution to the perched water near the tank farm. The chemical signatures of the various water sources are used to determine their impact on the perched water. The need for this study was based on the data gaps or needs identified in the MWTS report (DOE-ID 2003a) and is needed to meet the requirements of the OU 3-13 ROD.

Groundwater samples were collected from the perched water wells and aquifer wells that are listed in Table 2-1. The screened intervals for the perched wells sampled are shown in Table 2-2. The geochemical study included sampling perched wells near the tank farm up to four times over a period of approximately 1 year for hydrogen and oxygen isotopic analysis, metals and major cations (filtered), anions, tritium and strontium-90 (Table 2-1). The locations of perched wells sampled for the geochemical study are shown on Figure 2-3. The Wells MW-4-2 and STL-DP were identified in the geochemical study

[illegible]

[illegible]

[illegible]

Location	Date	Water		Nitrate		Alkalinity	Metals ^a	Anions ^b	Nitrate/ Nitrite as Nitrogen	TKN ^c	Strontium-90	TDS	Tritium
		δ ² H	δ ¹⁸ O	δ ¹⁵ N	δ ¹⁸ O								
Ponded Rain	Oct-04	x	x										
	Oct-04	x	x										
	Oct-04	x	x										
	Oct-04	x	x										
Snow	Feb-04	x	x			x	x	x	x				
	Feb-04	x	x			x	x	x	x				
	Feb-04	x	x			x	x	x	x				
Potable Water Supply	Sep-03	x	x			x	x	x	x				
	Dec-04	x	x			x	x	x	x				
	Feb-04	x	x			x	x	x	x				
	Jul-04	x	x			x	x	x	x				
Sewage Lagoons	Sep-03	x	x			x	x	x	x				
	Dec-04	x	x			x	x	x	x				
	Feb-04	x	x			x	x	x	x				
	Jul-04	x	x			x	x	x	x				
Steam Condensate	Dec-04	x	x			x	x	x	x				
	Feb-04	x	x			x	x	x	x				
	Feb-04	x	x			x	x	x	x				
CPP-603 Basin	Nov-04	x	x			x	x	x	x		x	x	x
	Nov-04	x	x			x	x	x	x		x	x	x
Drainage Ditch ^d	Jul-04	x	x			x	x	x	x				

a. Metals include barium, beryllium, boron, calcium, aluminum, arsenic, antimony, cadmium, chromium, cobalt, copper, magnesium, potassium, lead, iron, manganese, mercury, nickel, silver, selenium, sodium, thallium and zinc

b. Anions include bromide, chloride, fluoride, and sulfate

c. TKN is Total Kjeldahl Nitrogen

d. Water in ditch was fire water from Wells CPP-01 and CPP-02.

Table 2-2. Well construction details for perched wells.

Location	Screen interval (ft BGS)
33-2	85.8-105.8
33-3	111.8-122.0
33-4-1	98.2-118.25
37-4	99.9-109.9
55-06	93.1-113.1
CS-CH	188.5-198.5
MW-10-2	141-151
MW-1-4	326-336
MW-15	111.3-131.3
MW-2	102-112
MW-20-2	133.2-148.4
MW-24	53.5-73.5
MW-5-2	106.5-126.5
USGS-050	357-405

field sampling plan (DOE-ID 2003b) to be sampled, but both wells were dry during the period of the study and were not sampled. In addition, the Big Lost River sampling event identified in the Geochemical study field sampling plan (DOE-ID 2003b) did not occur because the Big Lost River did not flow. Although not part of the original geochemical study field sampling plan (DOE-ID 2003b), the sudden appearance of water in Well MW-15 during the summer of 2004 was also investigated as part of the geochemical study. Well MW-15 had been dry for approximately 2 years prior to the summer of 2004, when the water level increased by approximately 26 ft. The goal was to determine if the CPP-603 basins might be the source of the water in Well MW-15.

A limited sampling event for nitrogen and oxygen isotope ratios in nitrate occurred in September 2003 for perched Wells 55-06, MW-1-4, USGS-50, MW-5, 37-4 and MW-24. A second sampling event for nitrogen and oxygen isotope ratios in nitrate occurred in February and May 2004 for perched Wells 55-06, MW-5, MW-2, MW-20-2, MW-10-2, 37-4, MW-24, MW-1-4, USGS-50, CS-CH, 33-2, 33-3, and 33-4 (Figure 2-3). The SRPA Wells USGS-121, USGS-47, USGS-112, USGS-77, USGS-123, USGS-52, and ICPP-MON-A-230 were sampled for nitrogen and oxygen isotope ratios in nitrate to evaluate contaminant flux from the vadose zone near the tank farm area or the sewage treatment lagoons (see Figure 2-4).

The geochemical study also included sampling potential water sources such as the sewage plant effluent, ponded surface water, snow, water supply, steam condensate discharge, and fire line water. The locations of these source water samples are shown on Figure 2-4. In addition, samples were also collected from the CPP-603 south basin to evaluate the source of the water in MW-15. Three steam condensate samples were collected from discharge conduits located near the tank farm. Three ponded surface water samples were collected in late February to evaluate the chemical and isotopic signature of spring surface

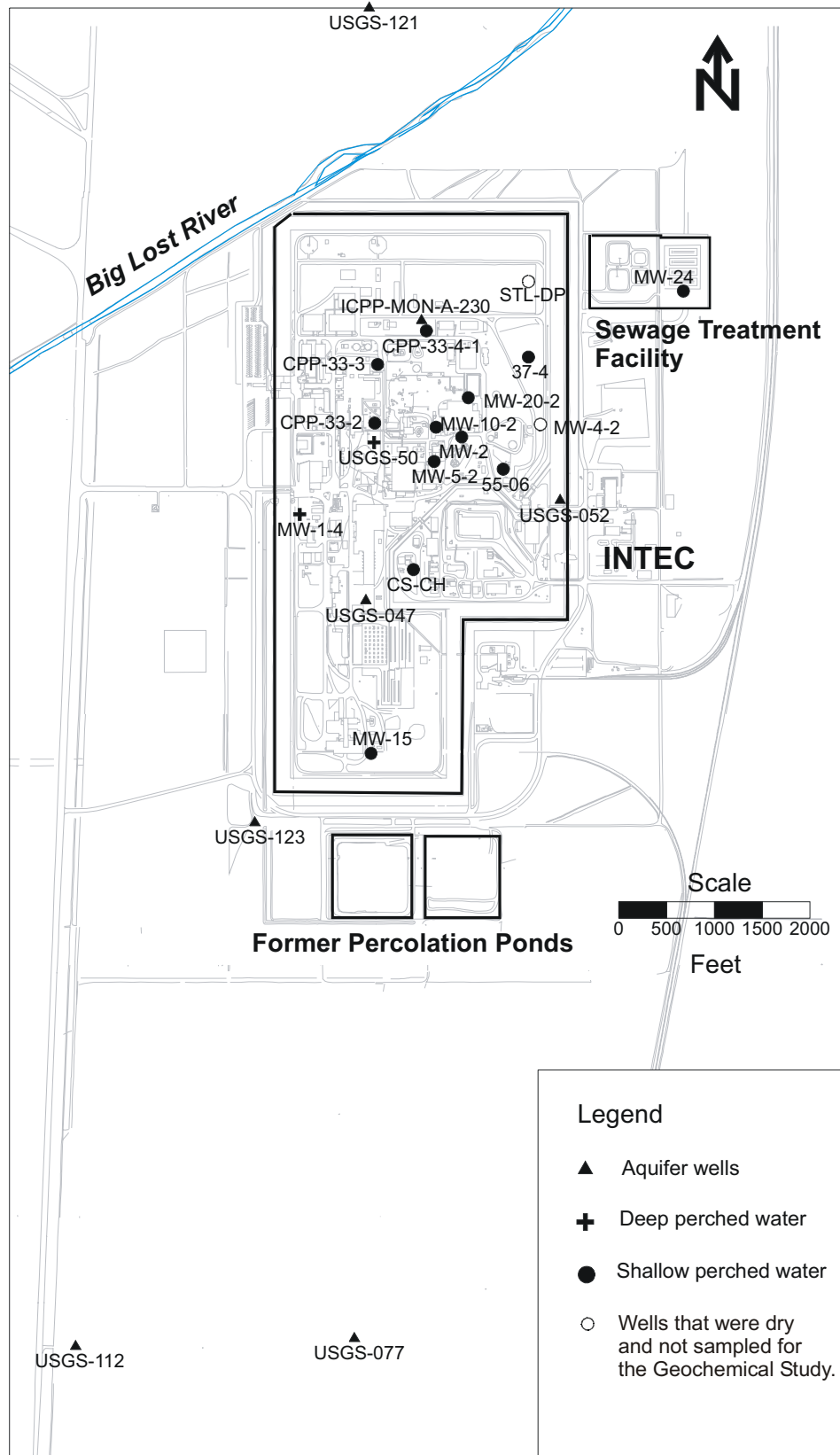


Figure 2-3. Map of INTEC showing geochemical study monitoring well sampling locations.

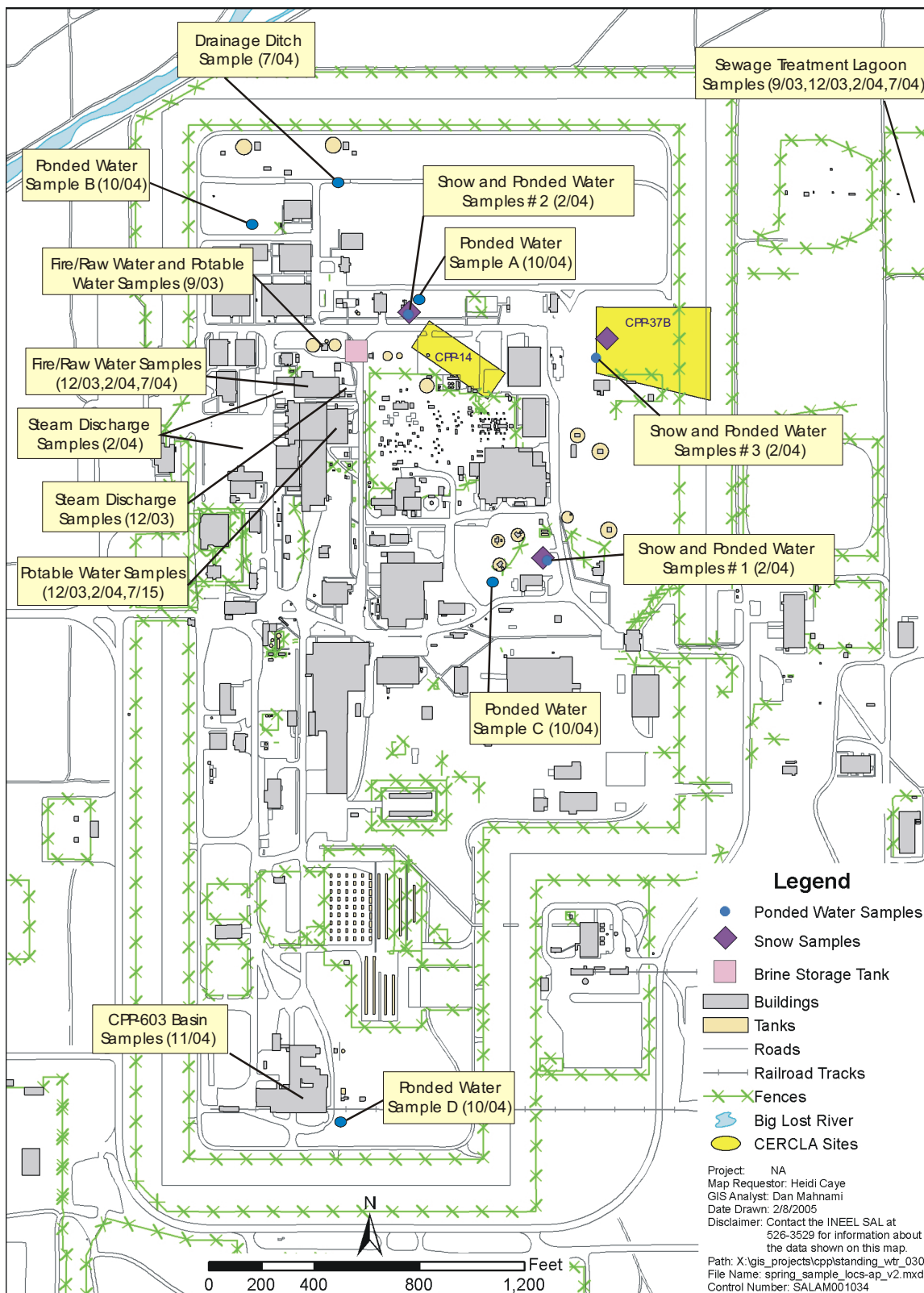


Figure 2-4. Location of geochemical study source water samples.

water infiltration. The approximate size of ponded water is shown on Figure 2-5. In addition, four ponded rain water samples were collected in late October 2004 for hydrogen and oxygen isotope analysis. Three snow samples were collected in late February 2003, prior to spring snow melt, and analyzed for oxygen and hydrogen isotopic ratios. The water supply, sewage plant effluent and fire-line water were sampled four times during a one-year period. The potable water supply was sampled after chlorination. The source water samples and list of analytes are summarized on Table 2-1.

The perched Wells, 33-2, 33-3, 33-4, 37-4, MW-24, MW-1-4, MW-10-2, MW-5-2, and MW-2, in the northern part of INTEC were instrumented with temperature, electrical conductivity, and water-level probes. In addition, Wells 55-06 and MW-20-2 have water-level and temperature probes. The conductivity data were to be used to evaluate the influence of the Big Lost River on the perched water in the northern part of INTEC, but the Big Lost River did not flow during the period of the geochemical study.

3. EVALUATION OF GEOCHEMICAL RESULTS

This section presents sampling results of the geochemical study and then discusses the potential sources of water for the perched water bodies. The flux of contaminants from the vadose zone into the aquifer is also examined based on nitrogen isotope results. Identification of water sources responsible for recharge of the perched water is essential for modeling and remediation of contamination because water provides the medium for transporting contaminants to the perched water and eventually to the aquifer. The goals of the geochemical evaluation are as follows:

- Characterize potential perched water sources based on major-ion chemistry and oxygen- and hydrogen-isotope data to determine water sources in perched wells
- Combine information on contaminant distributions, water-levels, major ion data, and stable isotope data to identify the most likely sources of water in perched wells.

Evaluating the influence of the Big Lost River was not possible because the Big Lost River did not flow during the period of the geochemical study from September 2003 to November 2004.

When radiological results are reported in the text of this document, only the concentrations are given; the associated analytical uncertainties are listed in Table 3-1, and are provided on a supplemental data CD in Appendix B. The minimum detectable activity for each radiological sample, and the complete data set from the water sampling conducted for the geochemical study are provided on the attached CD. An explanation of data qualifiers and validation flags is also given in Appendix B.

Metals samples were filtered to provide a representative and consistent data set for the geochemical analysis in order to use the metals data to determine sources of water and to evaluate geochemical processes. Although small colloidal particles can still pass through the 0.45 μm filters, the filtered fraction more closely represents the fraction of metals that are dissolved and, therefore, more mobile. Unfiltered samples were not taken for the geochemical study, because the dissolved fraction of metal concentrations or naturally mobilized fraction cannot be determined from the fraction that is mobilized by the acid added to preserve the sample. Perched water samples contain varying amounts of suspended solids, and the chemistry of the sample can be greatly altered when the acid used to preserve the sample is added.

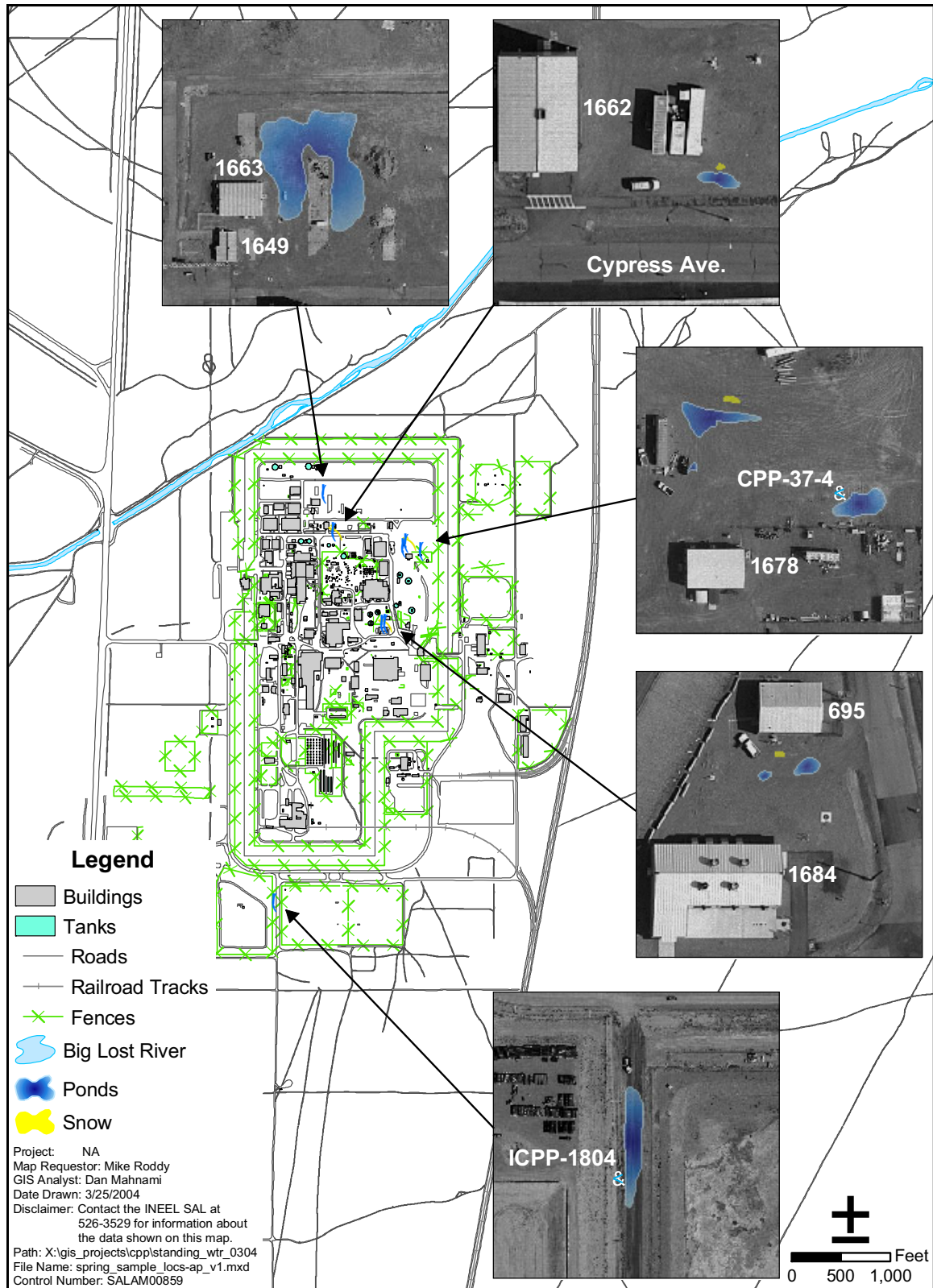


Figure 2-5. Ponded melt water location map for late February and early March 2004.

Table 3-1. Strontium-90 and tritium results for perched water and CPP-603 basin water samples.

Location	Date Sampled	Strontium-90			Tritium		
		pCi/L	+/-	Validation Flag ^a	pCi/L	+/-	Validation Flag ^a
33-2	9/23/2003	173	22.3		692	107	
33-2	2/11/2004	86.1	42.4	J	2040	128	
33-2	7/12/2004	115	15.6		1400	101	
33-2	10/4/2004	128	19.9		1380	114	
33-3	9/23/2003	2.53	0.402	J	296	96.6	J
33-3	2/12/2004	5.51	0.767	J	459	101	
33-3	7/14/2004	6.1	0.817		338	85.5	
33-3	10/5/2004	4.97	0.882	J	497	100	
33-4-1	9/17/2003	65.4	8.11		56	94.2	U
33-4-1	2/24/2004	52	12.5		64	82.6	U
33-4-1	Dup 2/24/2004	NA	NA		188	86.4	UJ
33-4-1	7/14/2004	57.6	7.8		122	87.7	U
33-4-1	10/5/2004	44.4	7.14		168	95.3	UJ
37-4	9/10/2003	16.6	2.1		606	96.3	
37-4	5/18/2004	36.6	4.92		751	100	J
37-4	7/12/2004	9.22	1.34		343	88.7	
37-4	10/6/2004	22.8	4.74		686	104	
55-06	9/16/2003	37400	4560		516	101	
55-06	2/19/2004	25800	2950		91.7	80.2	U
55-06	Dup 2/19/2004	35600	4060		539	100	
55-06	7/13/2004	37000	5390		178	81.3	UJ
55-06	10/11/2004	30200	4990		230	96.7	UJ
CS-CH	2/18/2004	0.547	0.131	UJ	564	100	
MW-10-2	9/18/2003	NA	NA		11400	302	
MW-10-2	2/24/2004	16900	2420		13000	331	
MW-10-2	7/12/2004	15800	2180		10500	200	
MW-10-2	10/5/2004	NA	NA		14200	256	
MW-1-4	9/18/2003	4.8	0.65	J	6820	187	
MW-1-4	5/25/2004	5.4	0.821	J	7180	194	
MW-1-4	Dup 5/25/2004	36.7	5.43	J	7080	196	
MW-1-4	7/14/2004	3.45	0.468	UJ	5490	151	
MW-15	10/11/2004	5330	1100	J	291	97.4	UJ
MW-15	Dup 10/11/2004	4620	801	J	392	99	
MW-2	2/19/2004	160000	17500		7350	248	
MW-2	7/13/2004	177000	22500		2620	118	
MW-2	10/6/2004	123000	17500	J	2090	124	
MW-20-2	9/16/2003	17700	2190		182	79.5	UJ
MW-20-2	2/25/2004	17200	1940		105	91.3	U
MW-20-2	7/13/2004	18500	2490		175	83.7	UJ
MW-20-2	10/6/2004	17400	3020		140	94.5	UJ

Table 3-1. (continued).

Location	Date Sampled	Strontium-90			Tritium		
		pCi/L	+/-	Validation Flag ^a	pCi/L	+/-	Validation Flag ^a
MW-24	9/9/2003	0.134	0.135	U	0	78.5	U
MW-24	2/25/2004	1.09	0.202	UJ	30.2	76.6	U
MW-24	7/15/2004	0.908	0.22		5.23	83.1	U
MW-24 Dup	7/15/2004	0.146	0.16	U	93.9	82.9	U
MW-24	10/26/2004	1.17	0.288	UJ	280	95.8	UJ
MW-5-2	9/15/2003	19400	2470		688	107	
MW-5-2	2/18/2004	16100	4170		569	101	
MW-5-2	7/13/2004	15400	1980		574	88.8	
MW-5-2	10/5/2004	45200	6320		2410	129	
USGS-050	5/18/2004	118	18.3		21300	324	
USGS-050 Dup	5/18/2004	116	16.1		22100	332	
USGS-050	7/13/2004	111	14.4		17700	268	
USGS-050	11/5/2004	139	23.6		18600	550	
CPP-603 BASIN	11/23/2004	126000	17100		16400	394	
CPP-603 Dup BASIN	11/23/2004	125000	18800		17700	409	

a. See Appendix B for explanation of data flags.

3.1 Radionuclide and Metals Results

Perched water sampling and analysis was conducted for tritium, strontium-90, metals, and anions as part of this investigation and in coordination with regular WAG 3 Group 4 sampling activities. Sample concentrations are compared with maximum contaminant levels (MCLs). However, these comparisons are for reference only, and are not intended to imply that the perched water bodies represent an aquifer capable of long-term use or as a potable water source. One goal of the perched water sampling was to correlate changes in contaminant concentrations with changes in water levels and to use this correlation to evaluate the impacts of water sources on the migration of contaminants. The determination of the sources driving contamination is a goal of this study.

3.1.1 Strontium-90

Strontium-90 results are presented in Table 3-1 and are generally consistent with past data. Trend plots for strontium-90 and perched water levels are included in Appendix A and summarized in Table 3-2. Most of the wells in the geochemical study exceed the EPA-defined MCL of 8 pCi/L and this was one of the reasons why the wells were selected for this study. The highest Sr-90 concentrations are in perched Wells MW-2, 55-06 and MW-5-2 southeast of the tank farm. The trend data indicate that strontium-90 concentrations do not appear to be correlated to changes in water levels in most wells (Table 3-2; Appendix A). Well MW-5-2 shows an increase in strontium-90 concentration of 29,800 pCi/L after a drop in water level of about 5.4 ft and corresponds with a doubling in the conductivity value for this well (see Section 3.2.2) and increasing concentrations of tritium and chloride.

Table 3-2. Select parameter changes at geochemical study well locations.

Well	Parameter	Parameter range		Sept (initial data)	Parameter change ^a		
		Minimum	Maximum		Feb/May	July	Oct/Nov
37-4	Water-level (elev-ft)	4803.62	4806.81	4804.08	1.86	0.14	0.63
	tritium (pCi/L)	343	751	606	145	-408	343
	Strontium-90 (pCi/L)	9.22	36.6	16.6	20	-27.4	13.6
	chloride (mg/L)	11.7	29.5	29.5	-1.5	-16.3	13.9
	$\delta^{18}\text{O}$ (‰ VSMOW)	-17.11	-16.9	-16.96	0.03	-0.18	0.21
	$\delta^2\text{H}$ (‰ VSMOW)	-132.4	-131.5	-132.4	0.8	-0.12	0.22
	conductivity (mmhos/cm)	0.337	0.814	0.814	-0.012	-0.465	0.468
33-2	Water-level (elev-ft)	4811.82	4816.74	4816.74	-4.54	0.61	2.29
	tritium (pCi/L)	692	2040	692	1348	-640	-20
	Strontium-90 (pCi/L)	86.1	173	173	-86.9	28.9	13
	chloride (mg/L)	55.6	83.6	83.6	-23.5	-4.5	20.6
	$\delta^{18}\text{O}$ (‰ VSMOW)	-17.31	-16.98	-17.31	0.11	0.22	-0.24
	$\delta^2\text{H}$ (‰ VSMOW)	-134.27	-131.96	-131.96	-2.31	1.08	0.59
	conductivity (mmhos/cm)	0.57	0.613	NA	0.583	-0.013	0.043
33-3	Water-level (elev-ft)	4795.75	4799.15	4799.11	-1.97	-1.37	0.33
	tritium (pCi/L)	296	497	296	163	-121	159
	Strontium-90 (pCi/L)	2.53	6.1	2.53	2.98	0.59	-1.13
	chloride (mg/L)	946	3140	986	2154	-1780	-414
	$\delta^{18}\text{O}$ (‰ VSMOW)	-16.69	-16.48	-16.48	-0.18	-0.03	0.03
	$\delta^2\text{H}$ (‰ VSMOW)	-131.26	-129.00	-129.47	-1.79	1.38	0.88
	conductivity (mmhos/cm)	3.79	6.52	NA	6.52/-1.62	-0.57	-0.54
33-4-1	Water-level (elev-ft)	4811.6	4814.56	4814.42	0.04	-2.86	2.96
	tritium (pCi/L)	ND	ND	-	-	-	-
	Strontium-90 (pCi/L)	44.4	65.4	65.4	-13.4	5.6	-13.2
	chloride (mg/L)	18.7	24.7	19.7	-1	6	-3.9
	$\delta^{18}\text{O}$ (‰ VSMOW)	-17.48	-17.33	-17.48	0.01	0.14	-0.14
	$\delta^2\text{H}$ (‰ VSMOW)	-135.1	-132.79	-134.77	0.73	1.25	-2.31
	conductivity (mmhos/cm)	0.46	0.492	NA	0.46	0.032	-0.027
55-06	Water-level (elev-ft)	4803.35	4808.5	4805.47	2.82	-1.13	0.37
	tritium (pCi/L)	516	539	516	23	-	-
	Strontium-90 (pCi/L)	25800	37400	37400	-11600	11200	-6800
	chloride (mg/L)	30.6	59.2	59.2	-23.2	-4.2	-1.2
	$\delta^{18}\text{O}$ (‰ VSMOW)	-17.36	-16.76	-16.76	-0.42	-0.11	-0.07
	$\delta^2\text{H}$ (‰ VSMOW)	-134.3	-128.86	-128.86	-3.85	-1.11	-0.48
	conductivity (mmhos/cm)	0.531	0.591	NA	0.591	-0.029	-0.031

Table 3-2. (continued).

Well	Parameter	Parameter range		Sept (initial data)	Parameter change ^a		
		Minimum	Maximum		Feb/May	July	Oct/Nov
MW-24	Water-level (elev-ft)	4841.22	4847.05	4846.04	0.79	0.04	0.09
	tritium (pCi/L)	ND	ND	-	-	-	-
	Strontium-90 (pCi/L)	0.134	1.17	-	-	0.908	-
	chloride (mg/L)	104	145	145	-41	11	3
	$\delta^{18}\text{O}$ (‰ VSMOW)	-15.57	-12.15	-12.15	-3.42	1.26	0.63
	$\delta^2\text{H}$ (‰ VSMOW)	-126.1	-112.5	-112.5	-13.6	5.17	2.73
	conductivity (mmhos/cm)	0.95	1.109	1.01	-0.054	-0.006	0.159
MW-1-4	Water-level (elev-ft)	4589.07	4593.42	4589.8	-0.59	3.67	0.54
	tritium (pCi/L)	5490	7180	6820	360	-1690	NA
	Strontium-90 (pCi/L)	3.45	36.7	4.8	0.6	-1.95	NA
	chloride (mg/L)	51.4	56.9	56.9	-3	-2.5	NA
	$\delta^{18}\text{O}$ (‰ VSMOW)	-17.22	-17.13	-17.22	0.04	0.05	NA
	$\delta^2\text{H}$ (‰ VSMOW)	-132.86	-132.13	-132.35	0.22	-0.73	NA
	conductivity (mmhos/cm)	0.888	0.914	NA	0.914	-0.34	NA
MW-2	Water-level (elev-ft)	4801.18	4808.44	4804.33	3.73	-1.09	0.35
	tritium (pCi/L)	2090	7350	NA	7350	-4730	-530
	Strontium-90 (pCi/L)	123000	177000	NA	160000	17000	-54000
	chloride (mg/L)	46.4	80.5	NA	46.4	8.5	25.6
	$\delta^{18}\text{O}$ (‰ VSMOW)	-16.4	-15.56	NA	-16.4	0.44	0.4
	$\delta^2\text{H}$ (‰ VSMOW)	-129.26	-124.6	NA	-129.26	2.42	2.24
	conductivity (mmhos/cm)	0.657	0.721	NA	0.721	-0.064	NA
MW-10-2	Water-level (elev-ft)	4768.23	4768.86	NA	4768.28/0.58	-0.4	-0.16
	tritium (pCi/L)	10500	14200	11400	1600	-2500	3700
	Strontium-90 (pCi/L)	15800	16900	NA	16900	-1100	NA
	chloride (mg/L)	58.1	65.1	65.1	-2.3	-0.4	-4.3
	$\delta^{18}\text{O}$ (‰ VSMOW)	-17.01	-16.96	-17.01	0.05	0	0.03
	$\delta^2\text{H}$ (‰ VSMOW)	-132.55	-129.56	-129.56	-2.99	1	-0.45
	conductivity (mmhos/cm)	0.869	0.917	NA	0.914/-0.045	0.02	0.028
MW-20-2	Water-level (elev-ft)	4776.2	4781.02	4776.22	4.63	-3.62	-0.33
	tritium (pCi/L)	ND	ND				
	Strontium-90 (pCi/L)	17200	18500	17700	-500	1300	-1100
	chloride (mg/L)	25.7	35.4	26.8	8.6	-8.1	-1.6
	$\delta^{18}\text{O}$ (‰ VSMOW)	-17.07	-16.31	-16.64	-0.43	0.56	0.2
	$\delta^2\text{H}$ (‰ VSMOW)	-132.66	-127.5	-127.6	-5.06	4.29	0.87
	conductivity (mmhos/cm)	0.579	0.598	NA	0.587	0.011	-0.019
MW-5-2	Water-level (elev-ft)	4798.92	4808.35	4807.33	0.57	-3.56	-5.42
	tritium (pCi/L)	569	2410	688	-119	5	1840

Table 3-2. (continued).

Well	Parameter	Parameter range		Sept (initial data)	Parameter change ^a		
		Minimum	Maximum		Feb/May	July	Oct/Nov
	Strontium-90 (pCi/L)	15400	45200	19400	-3300	-700	29800
	chloride (mg/L)	26.2	38	32.2	-4.9	-1.1	11.8
	$\delta^{18}\text{O}$ (‰ VSMOW)	-17.43	-16.52	-16.52	-0.8	-0.11	0.49
	$\delta^2\text{H}$ (‰ VSMOW)	-134.47	-128.46	-128.46	-6.01	0.38	3.99
	conductivity (mmhos/cm)	0.488	1.045	NA	0.503	-0.015	0.557
USGS-050	Water-level (elev-ft)	4530.19	4536.69	4534.09	2.6	-2.02	-0.47
	tritium (pCi/L)	17700	22100	NA	22100	-4400	900
	Strontium-90 (pCi/L)	111	139	NA	118	-7	28
	chloride (mg/L)	49.2	53.7	NA	53.7	-0.4	-4.1
	$\delta^{18}\text{O}$ (‰ VSMOW)	-17.21	-17.17	NA	17.21	0.04	-0.03
	$\delta^2\text{H}$ (‰ VSMOW)	-134	-133.1	NA	134	0.6	0.3
	conductivity (mmhos/cm)	0.774	0.807	NA	NA	0.774	0.033
<p>*from WAG 3, Group 4 field measurements</p> <p>*from sampling team measurements</p> <p>a. The parameter change is the difference between current (for example Feb/May data) versus the previous measurement (September data). In some instances, the Feb/May value is the initial data point rather than Sept.</p>							

3.1.2 Tritium

Tritium is present at detectable concentrations in ten of the sampled, perched water wells, but only USGS-050 exceeds the 20,000-pCi/L MCL (Table 3-1). The highest tritium concentration in Well USGS-050 was 22,100 pCi/L in May 2004. Trend plots for tritium and perched water levels are presented in Appendix A and summarized in Table 3-2. The tritium concentrations in most wells do not appear to be correlated to changes in water levels. An exception is the increase in tritium concentration in the fall October 2004 sample from MW-5-2 that correlates with a drop in water level of about 5.4 ft and corresponds with an increase in strontium-90 concentration and conductivity.

3.1.3 Metals and Anions

Metals results are presented in Table 3-3. The filtered metals results indicate that chromium concentrations are consistently high in 33-2 and above the MCL of 100 µg/L during three of the four sampling events. One sample from 33-4-1 was at 172 µg/L, but the other samples were below 10 µg/L. Manganese was above its secondary MCL (SMCL) of 50 µg/L in six samples, but did not occur above the SMCL more than once in any well. Mercury was not detected above 0.1 µg/L.

Iron concentrations greater than 300 µg/L occurred in five wells and one steam condensate sample. Elevated concentrations of iron are inconsistent with the relatively high dissolved oxygen concentrations reported for field measured parameters (see Section 3.2.2). Aluminum was above its SMCL of 200 µg/L in the same wells as elevated iron concentrations. The elevated dissolved aluminum concentrations are inconsistent with pH readings in the 7 to 8 range. The elevated iron and aluminum concentrations could represent filter break through or suspended particulates less than 0.45 µm in diameter.

Table 3-3. Metals results for perched water and source water samples.

Location	Date Sample Collected	Aluminum			Antimony			Arsenic			Barium			Beryllium			Boron			Cadmium			Calcium		
		µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a
Perched Water																									
33-2	09/23/2003	16.7	B	U	3.5	U		3.2	U		134			0.5	U		24.2	B		0.6	U		54500		
33-2	02/11/2004	39.8	B	U	7.11	U		3.7	U		118			0.26	U		35			0.65	U		52100		
33-2	07/12/2004	346	N	J	5.08	U		2.24	U		144			0.158	U		34.2			0.313	U		48600		
33-2	10/04/2004	31.6	B	U	5.08	U		2.24	U	UJ	137			0.08	U		33.9	E	J	0.313	U		52900		
33-3	02/12/2004	591	B		7.11	U		3.7	U		423			0.26	U		52.9			0.65	U		328000		
33-3	07/14/2004	14.7	UN		5.08	U		11.2	U		170			0.158	U		35.9			0.313	U		226000		
33-3	10/05/2004	274			5.08	U		2.24	U	UJ	161			0.08	U	J	40	E	U	0.44	B		185000		
33-4-1	09/17/2003	11.7	U		3.5	U		3.2	U		136			0.5	U		25.1	B		0.6	U		57300		
33-4-1	02/24/2004	30	U		7.11	U		3.7	U		152			0.26	U		22.9	B	U	0.65	U		59300		
33-4-1	07/14/2004	2590	N	J	5.08	U		2.24	U		382			0.58	B	U	30.3		U	0.313	U		73500		
33-4-1	10/05/2004	15.6	B	U	5.08	U		2.24	U	UJ	142			0.08	U	J	36.7	E	U	0.39	B		57000		
37-4	09/10/2003	11.7	U	UJ	3.5	U		3.2	U		261			0.5	U		18.7	B	J	0.6	U		87400		J
37-4	05/18/2004	789			5.08	U		2.24	U		271			0.158	U		43.5	B	U	1.2	B	U	87800		
37-4	07/12/2004	1700	N	J	5.08	U		2.24	U		129			0.158	U		25.3	B	U	0.313	U		40800		
37-4	10/06/2004	14.7	U	UJ	5.08	U	UJ	2.24	U	UJ	226	J		0.08	U	UJ	45.1	E	J	0.57	B	J	81800		J
55-06	09/16/2003	25.5	B	U	3.5	U		3.2	U		245			0.5	U		64.2			0.6	U		75400		
55-06	02/19/2004	30	U		7.11	U		3.7	U		182			0.26	U		44		U	0.65	U		61500		
55-06	02/19/2004*	30	U		7.11	U		3.7	U		184			0.26	U		45		U	0.65	U		61900		
55-06	07/13/2004	14.7	UN		5.08	U		2.24	U		172			0.158	U		43.8			0.313	U		59300		
55-06	10/11/2004	33.2	B		5.08	U		2.24	U		150			0.08	U		40.8	E		0.313	U		59500		J
CS-CH	02/18/2004	42.3	B	U	7.11	U		3.7	U		140			0.26	U		19	B		0.65	U		75800		
MW-10-2	02/24/2004	30	U		7.11	U		3.7	U		241			0.26	U		60.7			0.65	U		97200		
MW-10-2	10/05/2004	109	B		5.08	U	UJ	2.24	U	UJ	235			0.08	U		80.9	E	J	0.313	U		93600		
MW-1-4	09/18/2003	11.7	U		3.5	U		3.2	U		268			0.5	U		25.2	B		0.6	U		105000		
MW-1-4	05/25/2004	567		U	5.08	U		3.4	B	U	258			0.158	U		31.7	B	U	1.1	B		95100		
MW-1-4	05/25/2004*	985			5.08	U		2.24	U		262			0.158	U		29.2	B	U	1.2	B		95000		
MW-1-4	07/14/2004	14.7	UN		5.08	U		2.24	U		249			0.158	U		24.5	B	U	0.313	U		101000		
MW-15	10/11/2004	14.7	U	UJ	5.08	U	UJ	2.24	U	UJ	108	J		0.08	U	UJ	33.3	E	J	0.36	B	J	49000		J
MW-15	10/11/2004*	25.2	B	J	5.08	U	UJ	2.4	B	J	112	J		0.08	U	UJ	31.8	E	J	0.313	U	UJ	51400		J
MW-2	02/19/2004	30	U		7.11	U		3.7	U		306			0.26	U		195			0.65	U		76600		
MW-2	07/13/2004	14.7	UN		5.08	U		2.24	U		266			0.158	U		157			0.313	U		65100		
MW-2	10/06/2004	14.7	U		5.08	U	UJ	2.24	U	UJ	290			0.08	U		210	E	J	0.53	B	U	67900		
MW-20-2	09/16/2003	33.1	B	U	3.5	U		3.2	U		173			0.5	U		37.4			0.6	U		65600		
MW-20-2	02/25/2004	8590			7.11	U		3.94	B		275			0.273	B		85.4			0.65	U		73700		
MW-20-2	07/13/2004	14.7	UN		5.08	U		2.24	U		176			0.158	U		72.1			0.313	U		65900		
MW-20-2	10/06/2004	18.4	B	U	5.08	U	UJ	2.24	U	UJ	182			0.08	U		50	E	J	0.313	U		64200		
MW-24	09/09/2003	11.7	U	UJ	3.5	U		13.9	B		302			0.5	U		39.1		J	0.6	U		98400		J
MW-24	02/25/2004	30	U		7.11	U		15.4	B		247			0.26	U		36.5		U	0.65	U		88200		
MW-24	07/15/2004	14.7	UN		5.08	U		5.2	B		241			0.158	U		42			0.313	U		87400		
MW-24	07/15/2004*	14.7	UN		5.08	U		3.7	B		237			0.158	U		41.4			0.313	U		84400		
MW-24	10/26/2004	64.8	B		5.08	U	U	15.6	B	U	288			0.08	U		60.7	E	J	0.92	B	U	90600		
MW-5-2	09/15/2003	11.7	U		3.5	U		3.2	U		215			0.5	U		144			0.6	U		66300		
MW-5-2	02/18/2004	40.7	B	U	7.11	U		3.7																	

Table 3-3. (continued).

Location	Date Sample Collected	Chromium			Cobalt			Copper			Iron			Lead			Magnesium			Manganese			Mercury		
		µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a
Perched Water																									
33-2	09/23/2003	96.6			0.82	B		1.7	U	UJ	177			2.1	U		14400			3.3	B		0.1	U	UJ
33-2	02/11/2004	101			2.43	B		2.3	U		69.5	B	U	2.7	U		14000			27.9			0.066	U	
33-2	07/12/2004	1660			4.9	B		38.7			6620			1.7	B		12800			50.3			0.0472	U	
33-2	10/04/2004	105			0.541	U		2.6	B		282			4.4	B	U	14300			7.6	B		0.0472	U	
33-3	02/12/2004	9.39	B		3.88	B		2.3	U		6.53	U		2.7	U		101000			72.4			0.066	U	
33-3	07/14/2004	15.5			1.5	B		3.5	B		37.7	B	U	1.72	U		68300			20.4			0.0472	U	
33-3	10/05/2004	25			0.541	U		1.39	U		12.6	U		2.7	B	U	59800			10.8	B		0.0472	U	
33-4-1	09/17/2003	5.8	B		0.7	U		1.7	U		14.1	U		2.1	U		15200			3.8	B		0.1	U	
33-4-1	02/24/2004	6.83	B		1.49	U		2.7	B		74	B		2.7	U		15700			1.39	B		0.066	U	
33-4-1	07/14/2004	172			14.2	B		32.4			4180			11.5	B		18400			248			0.0472	U	
33-4-1	10/05/2004	5.8	B		0.541	U		1.7	B		12.6	U		1.72	U		15400			2	B		0.0472	U	
37-4	09/10/2003	6.3	B		0.7	U		1.7	U	R	14.1	U		2.1	U		28300		J	0.6	U		0.1	U	
37-4	05/18/2004	9.5	B		0.541	U		15.9	B		915			8.8	B		25900			38.4			0.0472	U	
37-4	07/12/2004	23			28.1	B		29.8			2360			5.6	B		11800			71.2			0.0472	U	
37-4	10/06/2004	6.9	B	J	0.71	B	J	10.1	B	J	12.6	U	UJ	1.72	U	UJ	25400		J	0.93	B	J	0.0472	U	UJ
55-06	09/16/2003	11.6			0.7	U		1.7	U	UJ	14.1	U		2.1	U		22600			0.6	U		0.1	U	UJ
55-06	02/19/2004	12.5			1.49	U		2.3	U		41.5	B	U	2.7	U		18600			0.68	U		0.066	U	
55-06	02/19/2004*	14.6			1.49	U		2.3	U		8.88	B	U	2.7	U		19100			1.5	B		0.066	U	
55-06	07/13/2004	15.3			0.541	U		1.74	B		263			1.72	U		16000			5.49	B		0.0472	U	
55-06	10/11/2004	5.7	B		0.541	U		1.39	U		26.1	B		1.72	U		15900			4.4	B		0.0472	U	
CS-CH	02/18/2004	3.82	B		1.49	U		2.3	U		24.7	B	U	2.7	U		19600			31.4			0.066	U	
MW-10-2	02/24/2004	2.36	U		1.49	U		24.5	B		6.53	U		2.7	U		26800			0.68	U		0.066	U	
MW-10-2	10/05/2004	2.1	B	U	0.541	U		1.39	U		12.6	U		1.8	B	U	26300			0.55	B	U	0.0472	U	
MW-1-4	09/18/2003	4.9	B		0.7	U		1.7	U		14.1	U		2.1	U		31500			6.4	B		0.1	U	
MW-1-4	05/25/2004	10.1			0.541	U		8.4	B		445			2	B	U	28400			21.6			0.0472	U	
MW-1-4	05/25/2004*	11.8			0.541	U		9.5	B		724			2.1	B	U	28500			26.4			0.0472	U	
MW-1-4	07/14/2004	4.3	B		0.541	U		1.9	B		12.6	U		1.72	U		29100			1.2	B		0.0472	U	
MW-15	10/11/2004	6.4	B	J	0.541	U	UJ	1.39	U	UJ	12.6	U	UJ	1.72	U	UJ	13800		J	0.72	B	J	0.0472	U	UJ
MW-15	10/11/2004*	6.6	B	J	0.541	U	UJ	1.39	U	UJ	12.6	U	UJ	1.72	U	UJ	14400		J	0.76	B	J	0.0472	U	UJ
MW-2	02/19/2004	3.28	B		1.59	B		2.3	U		49.7	B	U	2.7	U		21000			1.91	B		0.066	U	
MW-2	07/13/2004	4.2	B		0.541	U		1.39	U		12.6	U		1.72	U		17500			0.35	B		0.0472	U	
MW-2	10/06/2004	9	B		0.541	U		1.8	B		54.7	B		3.6	B	U	18400			7.7	B		0.0472	U	
MW-20-2	09/16/2003	6.5	B		0.7	U		1.7	U		14.1	U		2.1	B		17400			0.89	B		0.1	U	
MW-20-2	02/25/2004	39.3			6.3	B		14.2	B		9570			2.7	U		21300			172			0.066	U	
MW-20-2	07/13/2004	4.9	B		2.3	B		2.1	B		27.1	B	U	1.72	U		16800			14.9	B		0.0472	U	
MW-20-2	10/06/2004	6.5	B		0.541	U		16.4	B		13.5	B		3.6	B	U	17100			2.6	B		0.0472	U	
MW-24	09/09/2003	0.79	B		0.7	U		1.7	U	R	49.9	B	U	2.1	U		23400		J	1.9	B		0.1	U	
MW-24	02/25/2004	2.36	U		1.67	B		7.83	B		10.8	B	U	2.99	B		20600			1.31	B		0.066	U	
MW-24	07/15/2004	1.6	B		0.541	U		9.4	B		16	B	U	1.72	U		19600			1	B		0.0472	U	
MW-24	07/15/2004*	0.503	U		0.541	U		9	B		12.6	U		1.72	U		19500			0.296	U		0.0472	U	
MW-24	10/26/2004	1.8	B	U	0.541	U		8.2	B		30.2	B		1.72	U		21400			0.89	B		0.0472	U	
MW-5-2	09/15/2003	5.4	B		0.7	U		1.7	U	UJ	14.1	U		2.1	U		17600			0.6	U				

Table 3-3. (continued).

Location	Date Sample Collected	Nickel			Potassium			Selenium			Silver			Sodium			Thallium			Zinc		
		µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^A	Validation Flag ^A	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a	µg/L	Result Qualifier ^a	Validation Flag ^a
Perched Water																						
33-2	09/23/2003	13.6	B		7310			6.1	B	U	1.7	U		46300			2.9	B	U	1.2	U	UJ
33-2	02/11/2004	104			4250	B		4.26	U		1.61	U		48900			4.06	U		7.73	B	
33-2	07/12/2004	60.6			5770			2.81	U		0.835	U		45000			10	U		28.3		
33-2	10/04/2004	67.6			3910	B		2.81	U		0.835	U		54200			10	U		15.2	B	
33-3	02/12/2004	304			18200			4.26	U		3.14	B		853000			4.06	U		35.8		
33-3	07/14/2004	241			16700			3.7	B	U	0.835	U		515000			10	U		28.4		
33-3	10/05/2004	179			15800			4.4	B	U	0.835	U		506000			10	U		13.3	B	
33-4-1	09/17/2003	2	B		3080	BE		3.3	U		1.7	U		13800			4.7	B		54		
33-4-1	02/24/2004	3.77	B		2690	B		4.26	U		1.61	U		12400			4.06	U		22.1		
33-4-1	07/14/2004	219			3550	B		2.81	U		0.835	U		14100			10	U		94.7		
33-4-1	10/05/2004	0.69	U		3200	B		2.81	U		0.835	U		14700			10	U		14.7	B	
37-4	09/10/2003	1.8	U		4560	BNE	J	3.8	U		1.2	U		49600	NE	J	2.5	U		4.8	U	
37-4	05/18/2004	3.9	B		3990	B		5	B		0.835	U		37600			10	U		65.6		
37-4	07/12/2004	20.2	B		2980	B		2.81	U		1.3	B		18200			10	U		134		
37-4	10/06/2004	0.69	U	UJ	4260	B	J	10.6	B	UJ	0.835	U	UJ	43000		J	10	U	UJ	22.6		J
55-06	09/16/2003	5	B		6720			3.3	U		1.7	U		39100			2.5	U		1.2	U	UJ
55-06	02/19/2004	3.87	B		4590	B		4.26	U		1.61	U		30600			4.06	U		13.8	B	
55-06	02/19/2004*	3.63	B		4880	B		4.26	U		1.61	U		30700			4.06	U		8.62	B	
55-06	07/13/2004	12.1	B		3920	B		2.81	U		0.835	U		28800			10	U		5.49	B	
55-06	10/11/2004	4.5	B		3160	B		6	B	U	0.835	U		25100			10	U		39		
CS-CH	02/18/2004	76.4			3850	B		4.26	U		1.61	U		26600			4.06	U		72.5		
MW-10-2	02/24/2004	2.57	U		5780			4.26	U		1.61	U		44300			4.06	U		23.2		
MW-10-2	10/05/2004	0.69	U		6160			3.6	B	U	0.835	U		47200			10	U		2.7	B	
MW-1-4	09/18/2003	1.8	U		6350	E		3.3	U		1.7	U		34200			2.5	B		18.1	B	
MW-1-4	05/25/2004	3.2	B		8830			13.1	B	U	0.835	U		30400			10	U		29.8		
MW-1-4	05/25/2004*	3.6	B		8850			11.5	B	U	0.835	U		30200			10	U		29.3		
MW-1-4	07/14/2004	0.87	B		5890			2.81	U		0.835	U		29000			10	U		11.1	B	
MW-15	10/11/2004	0.69	U	UJ	2900	B	J	5.9	B	UJ	0.835	U	UJ	13800		J	10	U	UJ	12.9	B	UJ
MW-15	10/11/2004*	0.69	U	UJ	3070	B	J	6.4	B	UJ	0.835	U	UJ	14400		J	10	U	UJ	14.1	B	UJ
MW-2	02/19/2004	2.57	U		5030			4.26	U		1.61	U		49200			4.06	U		16.3	B	
MW-2	07/13/2004	0.69	U		4910	B		2.81	U		0.835	U		46100			10	U		4.9	B	
MW-2	10/06/2004	26	B		4950	B		2.81	U		0.835	U		57800			10	U		5.8	B	
MW-20-2	09/16/2003	1.8	U		8510	E		3.3	U		1.7	U		26500			3.7	B		1.2	U	
MW-20-2	02/25/2004	42.5			7550			4.8	B		1.61	U		29400			4.06	U		79.2		
MW-20-2	07/13/2004	9.9	B		5600			2.81	U		0.835	U		30300			10	U		6.2	B	
MW-20-2	10/06/2004	4.2	B	J	5450			2.81	U		0.835	U		32100			10	U		8.7	B	
MW-24	09/09/2003	2.7	B		15900	NE	J	3.8	U		1.2	U		99100	NED	J	3.6	B	U	4.8	U	
MW-24	02/25/2004	2.81	B		10100			4.26	U		1.61	U		78500			4.06	U		9.13	B	U
MW-24	07/15/2004	2.7	B		10400			2.81	U		0.835	U		73200			10	U		2.4	B	
MW-24	07/15/2004*	1.8	B		10100			2.81	U		0.835	U		72900			10	U		3.1	B	
MW-24	10/26/2004	8.1	B	J	9860			3.3	B	U	0.835	U		91200			10	U		18.9	B	
MW-5-2	09/15/2003	1.8	U		3990	B		3.3	U		1.7	U		30300			2.5	U		1.2	U	UJ
MW-5-2	02/18/2004	2.57	U		3280	B		4.26	U		1.61	U		24100			4.06	U		2.32	B	
MW-5-2	07/13/2004	0.77	B		3250	B		2.81	U		0.835	U		21100			10	U		1.7	B	
MW-5-2	10/05/2004	1	B	J	5250			5.1	B	U	0.835	U		42100			10	U		9.2	B	
USGS-050	05/18/2004	0.69	U		5300			2.81	U		0.835	U		55700			10	U		335		
USGS-050	05/18/2004*	0.69	U		5630			2.81	U		0.835	U		59000			10	U		480		
USGS-050	07/13/2004	0.69	U		6020			2.81	U		0.835	U		59400			10	U		190		
USGS-050	11/05/2004	1.2	B		5190			2.81	U	UJ	0.835	U		55800			10	U		12.4	B	
Source Water Samples																						
Pond/Snow Water #1	02/23/2004	2.57	U		871	B		4.26	U		1.61	U		13600			4.06	U		3.84	B	U
Pond/Snow Water #2	02/23/2004	2.57	U		1780	B		4.26	U		1.61	U		22400			4.06	U		10.8	B	U
Pond/Snow Water #3	02/23/2004	2.57	U		1640	B		4.26	U		2.29	B	U	53700			4					

a. * Duplicate

Elevated concentrations of boron, up to 210 µg/L, were observed in Wells MW-2 and MW-5-2 and appear to be related to the source of the strontium-90 contamination in these wells. Elevated boron concentrations are also associated with MW-20-2, 55-06 and MW-10-2. Boron would be present in the liquid wastes at the tank farm because boron was used as a neutron poison to prevent criticalities in the dissolver product solution. The boron concentrations in MW-24 are likely related to sewage effluent rather than a source of strontium-90.

The results for chloride, nitrate, and other anions are shown in Table 3-4. The only anion above an MCL is nitrate. Nitrate was above its MCL of 10 mg/L-N in eight wells with the highest concentration of 52.1 mg/L-N occurring in MW-1-4. Chloride concentrations ranged from 11.7 to 3140 mg/L. Chloride has an SMCL of 250 mg/L. Only Well 33-3 was above the chloride SMCL. Chloride concentration trends and perched water hydrographs are shown in Appendix A. The changes in chloride concentrations versus changes in water level are summarized in Table 3-2. In most wells, the change in chloride concentration cannot be correlated with changes in water level. Chloride concentrations in Well MW-20-2 appear to show some correlation to changes in water level with increases in water level corresponding to an increase in chloride concentration and decreases in water level corresponding to a decrease in chloride concentration.

3.1.4 Total Dissolved Solids and Total Kjeldahl Nitrogen Results

Total Dissolved Solids (TDS) concentrations were measured at 12 perched wells and the CPP-603 south basin (Table 3-5). A total of nineteen Total Kjeldahl Nitrogen (TKN) measurements were made at 13 wells, the sewage lagoons, and ponded water location #1 (Table 3-5). The TKN concentrations represent the total concentrations of organic nitrogen plus ammonia. In nearly all samples from the perched wells, TKN concentrations were less than 1 mg/L. One sample collected from MW-20-2 in February 2004 had 2.24 mg/L, but a sample collected in October 2004 only had 0.099 mg/L of TKN. The sewage effluent contained 16.8 mg/L of TKN for the sample collected in February 2004 and a sample of ponded water contained 2.68 mg/L of TKN. Well MW-24 located next to the sewage infiltration trenches contained less than 1 mg/L of TKN for a sample collected in October 2004. In general, the TKN values in the sewage effluent appear to be fully oxidized to nitrate by the time that the infiltrating sewage effluent reaches perched water monitoring Well MW-24 (DOE-ID 2003a).

3.1.5 Discussion of Contaminant Data and Water Sources

Concentrations of tritium and strontium-90 in perched water wells do not seem to be tied to changes in water levels in most wells. This would suggest that contamination is dispersed in the vadose zone and that water migrating from any source picks up contaminants along its migration pathway. Well MW-5-2 does appear to show contamination related to a specific source of water. An increase in strontium-90 and tritium concentrations in the October 2004 sample from MW-5-2 corresponds with a doubling in the conductivity value and a drop in water level of about 5.4 ft.

3.2 Perched Water Quality Results

The relative and absolute concentrations of the major cations and anions are water quality parameters that can be used to distinguish sources of water. The major cations are sodium, potassium, calcium, and magnesium. The major anions are chloride, sulfate, and bicarbonate. In addition, field measured parameters can also be used to complement the major ion parameters for source characterization and identification.

These data collected during this study are indicative of the period of sampling and may not reflect conditions when the Big Lost River flows or after a very wet winter with a substantial snow pack. There has not been flow in the Big Lost River near INTEC since 2000.

Table 3-4. Anion results for perched water and source water samples.

Location	Date Sample Collected	Alkalinity, Total as CaCO3			Chloride			Fluoride			Bromide			Nitrogen, Nitrate/Nitrite			Sulfate		
		mg/L	Result Qualifier	Validation Flag	mg/L	Result Qualifier	Validation Flag	mg/L	Result Qualifier	Validation Flag	mg/L	Result Qualifier	Validation Flag	mg/L	Result Qualifier	Validation Flag	mg/L	Result Qualifier	Validation Flag
Perched Water																			
33-2	09/23/2003	176			83.6	E	J	0.13			0.1	U		3.4		R	31.4		
33-2	02/11/2004	133			60.1			0.327	J		0	U		5.8			33.3		J
33-2	07/12/2004	150			55.6		J	0.315	J		0	U		5.3			31.4		
33-2	10/04/2004	91.1			76.2			0.283	J	J	0.231	J		4.99		J	33.8		
33-3	09/23/2003	90			986	E	J	0.1	U		0.1	U		14.6		R ^b	166		
33-3	02/12/2004	59.5			3140			0.152	J		0.43	J		8.1			92.2		J
33-3	07/14/2004	65.6			1360		J	0.212	J		0.345	J		10.4			140		
33-3	10/05/2004	NA			946			0.237	J	J	0.387	J		0.28		J	151		
33-4-1	09/17/2003	182			19.7	E	J	0.17			0.1	U		2.9		R ^b	29.4		
33-4-1	02/24/2004	159			18.7			0.107	J		0	U		2.6		J	28.8		
33-4-1	07/14/2004	161			24.7		J	0.217	J		0	U		4			32.9		
33-4-1	10/05/2004	127			20.8			0.205	J	J	0	U		2.86		J	28.8		
37-4	09/10/2003	232			29.5			0.2			0.1	U		24.2		J	66.1		
37-4	05/18/2004	220			28			0.152	J		0	U		19			65.2		
37-4	07/12/2004	106			11.7		J	0.249	J		0	U		7.5			28.1		
37-4	10/06/2004	187			25.6			0.238	J	J	0.218	J		1.38		J	59.3		
55-06	09/16/2003	213			59.2	E	J	0.15			0.1	U		16.8		R ^b	35.5		
55-06	02/19/2004	187	H	J	36			0.146	J		0	U		5		J	33.7		
55-06	DUP 02/19/2004	186	H	J	36.1			0.141	J		0	U		5.25		J	33.4		
55-06	07/13/2004	173			31.8		J	0.232	J		0	U		4.74			32		
55-06	10/11/2004	170			30.6		J	0.22	J		0	U		4.26			31.1		J
CS-CH	02/18/2004	130			87.8			0.279	J		0.276	J		8.1			49		J
MW-10-2	09/18/2003	263			65.1	E	J	0.11			0.1	U		22.2		R ^b	40.3		
MW-10-2	02/24/2004	216			62.8			0.168	J		0.038	U		24		J	38.4		
MW-10-2	07/12/2004	NA			62.4		J	0.303	J		0.153	J		22			40.5		
MW-10-2	10/05/2004	NA			58.1			0.251	J	J	0.224	J		1.02		J	38.4		
MW-1-4	09/18/2003	151			56.9	E	J	0.1	U		0.1	U		52.1		R ^b	27.9		
MW-1-4	05/25/2004	141			53.9		J	0.263	J		0.222	J		52			29.7		
MW-1-4	DUP 05/25/2004	145			53.5		J	0.27	J		0.237	J		52			29.8		
MW-1-4	07/14/2004	146			51.4		J	0.263	J		0	U		45.3			27.9		
MW-15	DUP 10/11/2004	150			16.7		J	0.268	J		0	U		3.01			23.9		J
MW-15	10/11/2004	147			16.7		J	0.265	J		0	U		2.95			23.8		J
MW-2	02/19/2004	185	H	J	46.4			0.185	J		0.042	U		11.4		J	27.5		
MW-2	07/13/2004	199			54.9		J	0.303	J		0	U		5.9			23.6		
MW-2	10/06/2004	129			80.5			0.296	J	J	0.236	J		1.54		J	24		
MW-20-2	09/16/2003	182			26.8	E	J	0.13			0.1	U		9.2		R ^b	34.9		
MW-20-2	02/25/2004	211	H	J	35.4			0.145	J		0	U		5.1		J	27.9		
MW-20-2	07/13/2004	204			27.3		J	0.224	J		0	U		5.5			38.6		
MW-20-2	10/06/2004	177			25.7			0.233	J	J	0	U		3.75		J	41		
MW-24	09/09/2003	244			145			0.1			0.1	U		6.2		J	39.8		
MW-24	02/25/2004	237	H	J	104			0.12	J		0	U		12.5		J	32.2		
MW-24	07/15/2004	224			115		J	0.207	J		0	U		6.18		J	28.9		

Table 3-4. (continued).

			Alkalinity, Total as CaCO3			Chloride			Fluoride			Bromide			Nitrogen, Nitrate/Nitrite			Sulfate		
Location		Date Sample Collected	mg/L	Result Qualifier	Validation Flag	mg/L	Result Qualifier	Validation Flag	mg/L	Result Qualifier	Validation Flag	mg/L	Result Qualifier	Validation Flag	mg/L	Result Qualifier	Validation Flag	mg/L	Result Qualifier	Validation Flag
MW-24	DUP	07/15/2004	223			118		J	0.199	J		0	U		7.35		J	28.9		
MW-24		10/26/2004	240			141		J	0	U		0	U		11.9			32.6		
MW-5-2		09/15/2003	201			32.2	E	J	0.18			0.1	U		6.8		R ^b	29.3		
MW-5-2		02/18/2004	157			27.3			0.373	J		0	U		5.1			27.2		J
MW-5-2		07/13/2004	155			26.2		J	0.34	J		0	U		5.07			26.7		
MW-5-2		10/05/2004	233			38			0.283	J	J	0.216	J		1.31		J	22.6		
USGS-050		05/18/2004	133			53.7			0.247	J		0	U		27			37.3		
USGS-050	DUP	05/18/2004	134			52.6			0.237	J		0	U		27			37.5		
USGS-050		07/13/2004	135			53.3		J	0.354	J		0	U		28.5			37.5		
USGS-050		11/05/2004	136		J	49.2			0.357	J		0	U		3.93		J	38.3		
Source Water Samples																				
Ponded/Snowmelt #1		02/23/2004	55.4			17.5		J	0.227	J		0.406	J		2.75		J	25		
Ponded/Snowmelt #2		02/23/2004	301			21.1		J	0.146	J		0	U		3.12		J	2.2		
Ponded/Snowmelt #3		02/23/2004	113			205		J	0.151	J		0.293	J		0.82		J	9.16		
Sewage Lagoons		09/11/2003	197		J	157	E	J	0.1	U		0.1	U		1.1		R ^b	43.9		
Sewage Lagoons		12/03/2003	444			81.7		J	0.18	J		1.07			0.58			20.1		
Sewage Lagoons		02/25/2004	231			96.6		J	0.234	J		0	U		0.07		J	25.5		
Sewage Lagoons		07/15/2004	257			61.3		J	0.274	J		0	U		0.01	J	U	33.9		
Steam Condensate ^c		12/03/2003	19.3			0.007	U		0	U		0.107	J	U	0	U		0.034	U	
Steam Condensate ^d		02/25/2004	4.08	J		0	U		0	U		0	U		0	U	UJ	0.46	J	
Steam Condensate ^e		02/25/2004	18.5			0	U		0	U		0	U		0	U	UJ	0	U	
CPP-603 BASIN		11/23/2004	106			47.6			0.202	J		0	U		39.7			23.6		
CPP-603 BASIN	DUP	11/23/2004	83.5			48.2			0.194	J		0	U		38.6			23.6		
WATER SUPPLY		09/10/2003	156			13.2			0.12			0.1	U		0.74		J	23.1		
WATER SUPPLY		12/03/2003	276			14.1		J	0.157	J		0.937			0.73			22.4		
WATER SUPPLY		02/25/2004	150			14		J	0.256	J		0	U		0.77		J	22.7		
WATER SUPPLY		07/15/2004	150			14.1		J	0.223	J		0	U		0.7			22.8		
Drainage Ditch		07/21/2004	145			14.9			0.24	J		0	U		0.48		J	23.3		
FIRE/RAW Water		09/10/2003	154			13.7			0.13			0.1	U		0.78		J	22.9		
FIRE/RAW Water		12/03/2003	274			14.1		J	0.165	J		0.963			0.7			23.1		
FIRE/RAW Water		02/25/2004	152			15.2		J	0.238	J		0	U		0.94		J	23.2		
FIRE/RAW Water		07/15/2004	145			14.5		J	0.243	J		0	U		0.59		J	23.1		

a. See Appendix B for explanation of data flags.

b. The "R" flag is due to missed hold times of 48 hours for nitrite. Although flagged "R" , the results are considered acceptable because nitrate was the analyte of interest and samples were analyzed within the hold time for nitrate/nitrite as nitrogen.

c. East side of CPP-606

d. Building CPP-637

e. West side of CPP-606

Table 3-5. TDS and TKN results for perched water and source water samples.

Location	Date	TDS mg/L	LF ^a	VF ^{a,b}	TKN mg/L	LF	VF
33-2	10/04/2004	370			0.147	J	J
33-3	10/05/2004	-			0.275		J
33-4-1	02/24/2004	275			-		
33-4-1	02/24/2004	448			-		
33-4-1	10/05/2004	271			0.309		J
37-4	05/18/2004	518		R	0.254		J
37-4	10/06/2004	485			0.393		J
55-06	02/19/2004	363	H	J	-		
55-06	02/19/2004	539	H	J	-		
55-06	DUP 02/19/2004	359	H	J	-		
55-06	10/11/2004	305	H	J	0.037	U	
MW-1-4	05/25/2004	646			0.715		
MW-1-4	DUP 05/25/2004	645			-		
MW-2	02/19/2004	446	H	J	-		
MW-2	02/19/2004	800	H	J	-		
MW-2	10/06/2004	411			0.09	J	J
MW-5-2	10/05/2004	610			0.564		J
MW-10-2	02/24/2004	1070			-		
MW-10-2	10/04/2004	-			0.192	J	J
MW-15	10/11/2004	253	H	J	0.078	J	J
MW-15	DUP 10/11/2004	254	H	J	0.055	J	J
MW-20-2	02/25/2004	368			2.24		J
MW-20-2	10/06/2004	332			0.099	J	J
MW-24	02/25/2004	560			-		
MW-24	02/25/2004	840			-		
MW-24	10/26/2004	-			0.56		J
USGS-050	05/18/2004	501		R	0.262		J
USGS-050	DUP 05/18/2004	480		R	-		
USGS-050	11/05/2004	441			0.589		
CPP-603 BASIN	11/23/2004	435	H	J	-		
CPP-603 BASIN	DUP 11/23/2004	430	H	J	-		
Pond/snowmelt #1	02/23/2004	-			2.68		
Sewage Lagoons	02/25/2004	-			16.8		

a. "LF" means laboratory data flag. "VF" means validation flag.

b. See Appendix B for explanation of validation and laboratory flags.

3.2.1 Water Quality Data

The known sources of water that could cause perched zones and move contamination include the sewage treatment lagoons, infiltrating precipitation, the Big Lost River, lawn irrigation, and leaking water-supply, and steam lines. The sewage effluent from the sewage treatment lagoons actually infiltrates into the subsurface at the sewage infiltration trenches. The source of water for the water-supply, lawn-irrigation, fire-water, and steam lines is the SRPA. The chemical signature of the water from the SRPA and other sources can be used to determine the proportions of water from various sources in the perched water wells. The concentrations of the major cations and anions are shown in Tables 3-3 and 3-4.

A graphical representation of the relative major ion composition of these water sources is shown on a Piper diagram (Figure 3-1). The potable water supply is chlorinated, but plots in the same area (calcium-bicarbonate water) as the raw water on the Piper diagram. The effluent from the sewage treatment plant plots in a position on the Piper diagram that reflects higher sodium and chloride concentrations than in the water supply wells. The ponded water samples showed a wide range of compositions from relatively dilute calcium-bicarbonate water with low chloride (17.5 mg/L) to relatively high sodium and chloride (205 mg/L) composition. This is also reflected in the plot of calculated total dissolved solid concentrations Figure 3-2. The steam condensate water is the most dilute, as expected, of all the potential source waters (Figure 3-2).

The Piper diagram for all the perched water samples (Figure 3-3) shows that the anions are dominated by the bicarbonate ion and that the cations are dominated by the calcium ion. All the water in the shallow perched water zone near the tank farm displays a common pattern, with calcium being the most common cation, sodium slightly lower in molality, moderate chloride, and elevated bicarbonate. Most of the perched wells plot in three groups. Group 1 includes 33-4-1, MW-15, and MW-5-2 and plots near the compositions of the raw/potable water. The second group includes 37-4, 55-06, MW-10-2, MW-20-2, MW-2 and one sample from MW-5-2. This group has a composition between the raw/potable water supply and the sewage lagoons and ponded water. The third group plots between the raw/potable water supply and the sewage lagoons and ponded water, but plots closer to the sewage lagoons and ponded water. This group includes MW-24, as expected, along with 33-2 and USGS-050.

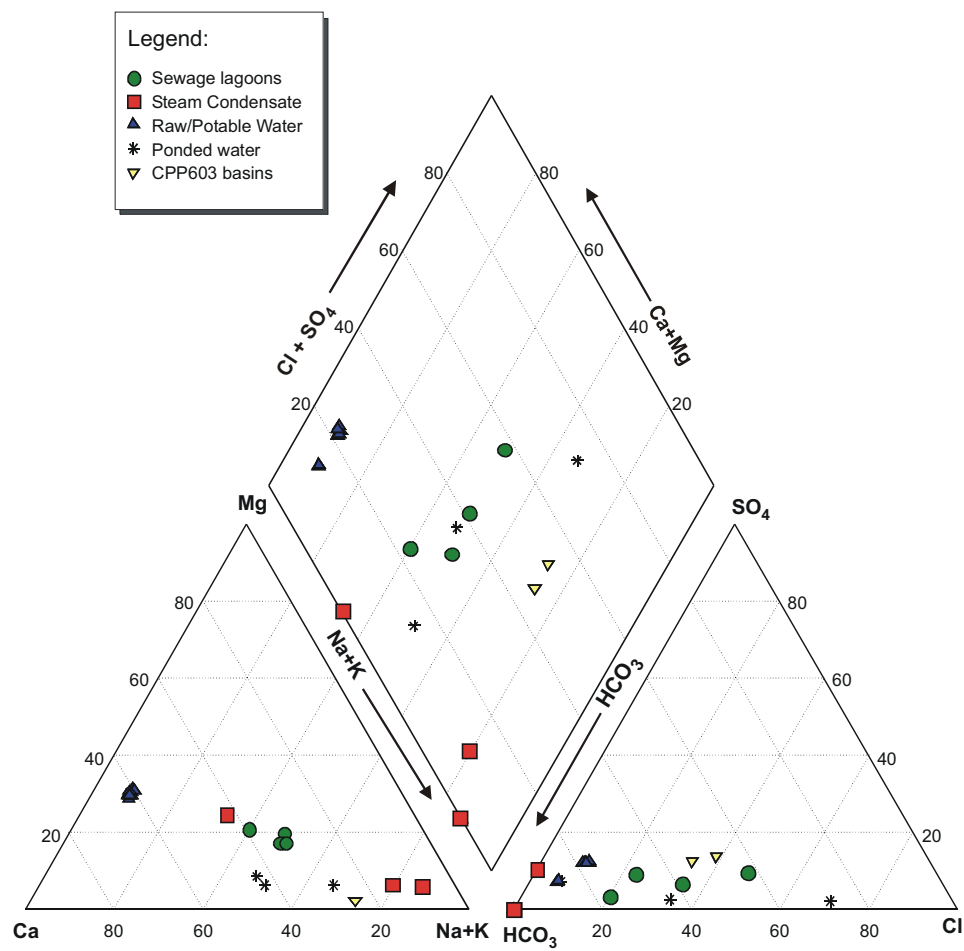


Figure 3-1. Piper diagram for potential water sources.

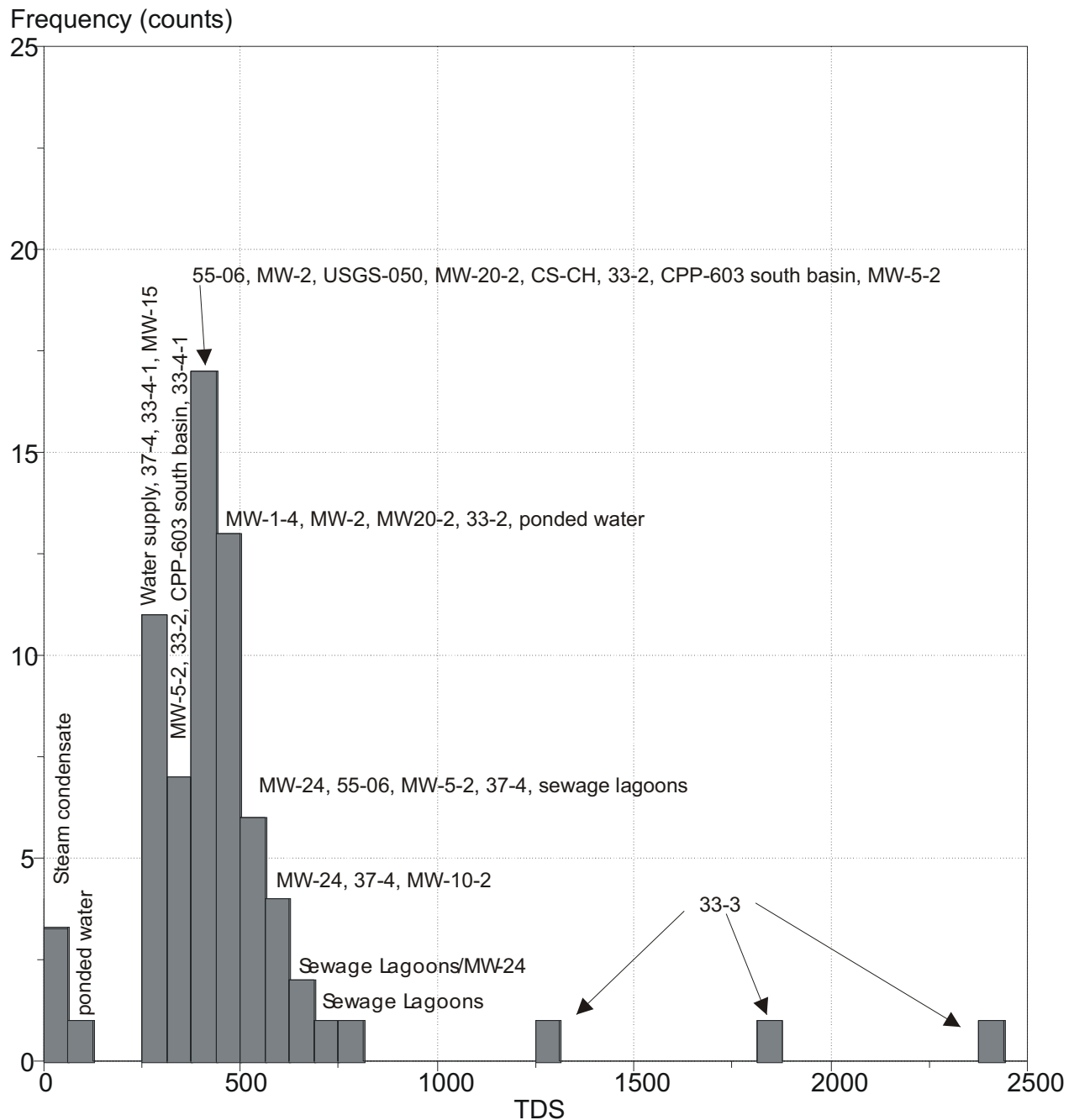


Figure 3-2. Histogram of TDS concentrations in perched water and source water samples.

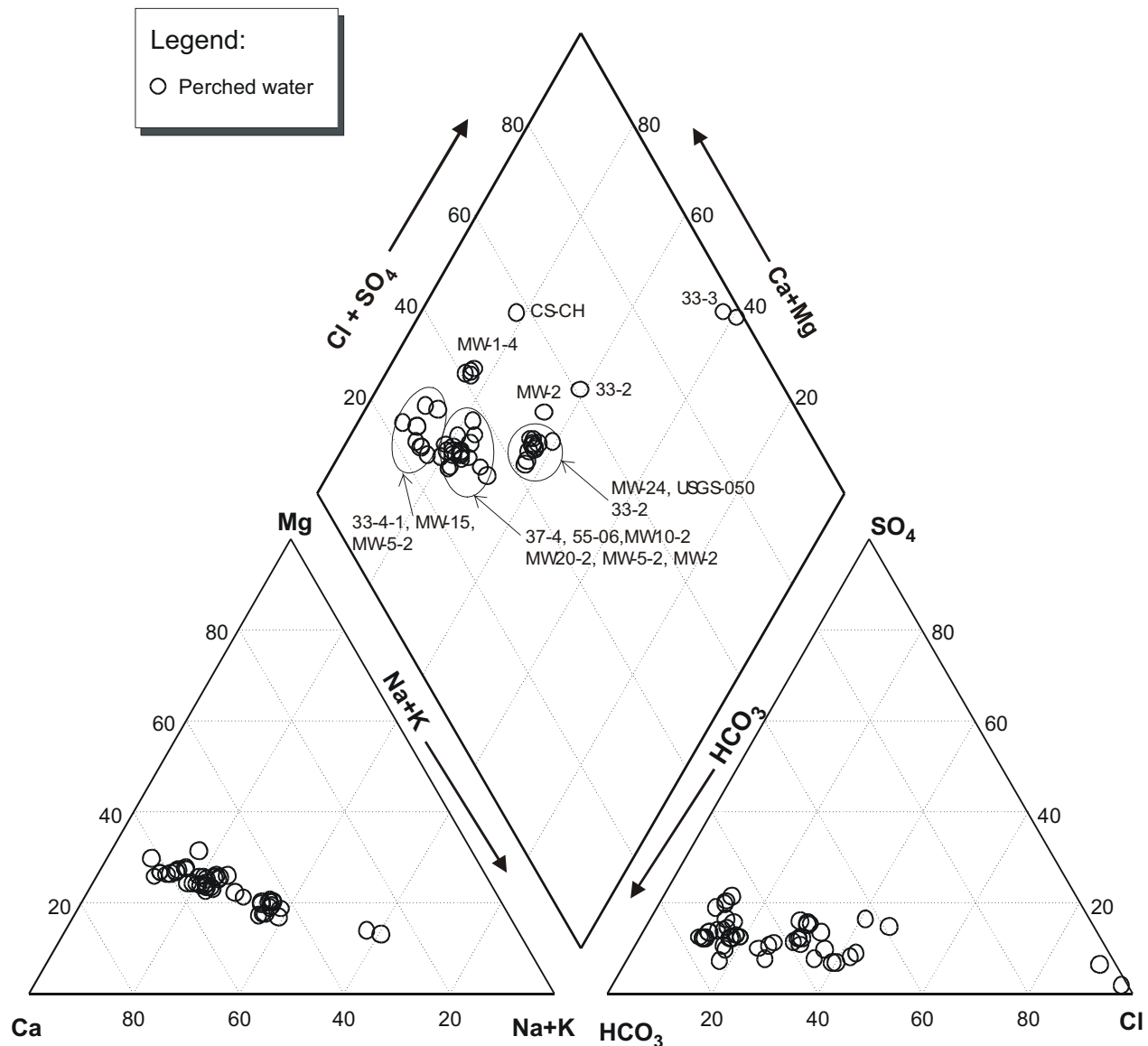


Figure 3-3. Piper trilinear water quality diagram for perched water samples.

The three wells, MW-1-4, 33-3, and CS-CH, plot as outliers on the Piper diagram compared to the other perched water samples. The two wells, Well 33-2 and Well MW-2, plot as outliers in one round. The deep perched water samples from MW-1-4 are shifted to higher chloride and sulfate. As noted above, Well 33-3 has elevated cation and anion concentrations that are indicative of brine contamination (Figure 3-2). The sample from the CS-CH has higher chloride concentrations, but the relative concentrations of the major cations are similar to MW-1-4.

3.2.2 Physical Parameter Data

The data for field measured parameters including temperature, pH, dissolved oxygen, and specific conductance are presented in Table 3-6 for perched wells sampled for the geochemical study. The data for field parameters can be used as indicators of contamination and water source characteristics. Except for one sample from 37-4, the conductivity values for all the perched water samples were greater than

that of fire/raw water supply. The pH values for perched wells ranged from 6.78 to 8.1. The specific conductance values for the perched water wells showed a wide range from 0.337 to 6.52 mS/cm, but most perched wells were in the range of 0.5 to 1 mS/cm. The highest specific conductivity values occur at Well 33-3. The conductivity results versus changes in water level are summarized in Table 3-2 and Appendix A.

In addition to the field measured conductivity, temperature and water levels, continuous conductivity; temperature and water level readings were taken with downhole probes. Trend plots of the automated downhole data and field measurements are shown in Appendix A.

3.2.3 Discussion of Water Quality Data and Physical Parameter Data

The major ion concentrations in most wells are not definitive with respect to potential water sources. The compositions of major ions have probably been modified during migration in the vadose zone. However, a few wells are similar to identified water sources. The concentrations of major ions and anions in Wells 33-4-1, MW-15 and MW-5-2, except for October 2004 sample, are similar to that of the fire/raw water and potable water supply. Well 33-3 has cation and anion concentrations that are indicative of brine contamination (Tables 3-3 and 3-4). The water in this well shows brine contamination and is located near a brine storage tank (CPP-736) and brine pump house (CPP-1610). The major ion concentrations in MW-24 are similar to the effluent to the sewage lagoons when taking into consideration the changes in major ion chemistry due to oxidation of reduced nitrogen species present in the effluent as described in detail in the MWTS report (DOE-ID 2003a).

The field-measured conductivity data were examined for changes versus water levels. Most wells, except for 37-4 and MW-5-2, showed relatively consistent conductivity values (Table 3-6; Appendix A). The conductivity for the July 2004 sample from 37-4 collected is about one-half the readings for the other sampling dates. The sample collected in October 2004 from MW-5-2 had a conductivity value twice as high as the previous samples. The water source causing the increase in conductivity in MW-5-2 is unknown, based on data from known potential sources.

The automated conductivity measurements showed more variation than the field measured conductivity measurements. A pronounced spike in conductivity occurs in MW-5-2 in August through September 2004. A spike also occurs in MW-10-2 in late October 2004 after the final geochemical study sample was taken.

Table 3-6. Field parameters for perched water and source water samples.

Well Name	Date Sampled	Time Sampled	Temperature (°C)	pH	Electrical Conductivity (mmhos/cm)	Dissolved Oxygen (mg/L)
33-2	9/22/2003	Water full of red sediment, doesn't clean up during purging				
33-2	2/11/2004	1110	15.94	7.74	0.583	6.26
33-2	7/12/2004	1016	18.11	7.43	0.57	6.67
33-2	10/4/2004	1122	18.02	7.8	0.613	6.91
33-3	9/23/2003	Went dry after purging				
33-3	2/11/2004	1142	12.12	7.28	6.52	6.22
33-3	5/18/2004	1314	19.6	7.46	4.75	5.03

Table 3-6. (continued).

Well Name	Date Sampled	Time Sampled	Temperature (°C)	pH	Electrical Conductivity (mmhos/cm)	Dissolved Oxygen (mg/L)
33-3	5/19/2004	1354	20.27	7.37	4.9	5.9
33-3	7/14/2004	957	20.13	7.11	4.33	5.66
33-3	10/4/2004	1355	19.92	7.77	3.79	5.41
33-3	10/5/2004	1008	18.99	7.62	4.04	5.12
33-4-1	9/7/2003	1510	Not measured.			
33-4-1	2/24/2004	1146	13.68	7.26	0.46	-
33-4-1	7/14/2004	1427	13.43	7.54	0.492	7.99
33-4-1	10/4/2004	1528	15.06	7.78	0.465	7.81
37-4	9/10/2003	1309	11.4	7.72	0.814	6.9
37-4	5/18/2004	1414	11.93	7.61	0.802	7.77
37-4	7/12/2004	1400	15.36	7.83	0.337	7.56
37-4	10/6/2004	1015	11.74	8.05	0.805	6.59
55-06	9/16/2003	1203	Not measured.			
55-06	2/19/2004	1002	11.47	7.71	0.591	7.4
55-06	7/13/2004	1242	15.7	7.27	0.562	7.26
55-06	10/11/2004	1357	13.86	7.77	0.531	6.81
CS-CH-2	2/18/2004	1345	11.53	7.31	0.721	-
MW-1-4	9/7/2003	936	Not measured.			
MW-1-4	5/25/2004	1002	13.79	7.29	0.914	7.09
MW-1-4	7/14/2004	1435	17.04	7.28	0.888	6.23
MW-1-4	10/6/2004	Not measured.				
MW-2	9/16/2003	Doesn't have enough water to sample.				
MW-2	2/19/2004	1238	20.53	7.29	0.696	4.24
MW-2	7/13/2004	0.944	22.89	7.13	0.657	3.89
MW-5-2	9/15/2003	1330	Not measured.			
MW-5-2	2/18/2004	1250	18.52	7.29	0.503	5.28
MW-5-2	7/13/2004	1038	19.74	7.07	0.488	4.97
MW-5-2	10/5/2004	1131	22.96	7.34	1.045	2.3
MW-10-2	9/8/2003	Went dry after purging				
MW-10-2	2/24/2004	1025	16.35	7.4	0.914	7.08
MW-10-2	5/18/2004	1103	16.74	7.48	0.869	5.48

Table 3-6. (continued).

Well Name	Date Sampled	Time Sampled	Temperature (°C)	pH	Electrical Conductivity (mmhos/cm)	Dissolved Oxygen (mg/L)
MW-10-2	7/12/2004	1119	16.92	7.29	0.889	6.64
MW-10-2	10/4/2004	1000	16.98	7.65	0.917	5.82
MW-10-2	10/5/2004	920	16.51	7.74	0.898	5.98
MW-15	10/5/2004	1057	17.36	7.78	0.427	6.22
MW-20-2	9/16/2003	1443	Not measured.			
MW-20-2	2/25/2004	1439	14.39	7.78	0.587	5.76
MW-20-2	7/13/2004	1346	17.52	7.23	0.598	7.65
MW-20-2	10/6/2004	1144	19.5	7.55	0.579	0.693
MW-24	9/9/2003	1342	9.33	6.97	1.01	6.4
MW-24	2/25/2004	945	9.61	7.02	0.956	5.66
MW-24	7/15/2004	947	10.63	6.78	0.95	5.84
MW-24	10/6/2004	1132	9.97	7.33	1.109	8.61
USGS 50	9/15/2003	Couldn't get a portable pump, collected only nitrogen/oxygen data.				
USGS-50	5/18/2004	1500	Not measured.			
USGS-50	7/13/2004	1442	18.45	7.71	0.774	7.31
USGS-50	11/5/2004	1424	17.52	8.1	0.807	6.2
Fire/Raw water	9/10/2003	857	12.33	7.87	0.379	7.48
Water Supply	9/10/2003	910	14.18	7.84	0.381	7.62

3.3 Hydrogen and Oxygen Stable Isotope Ratios

In addition to water quality data (major cations and anions) and physical parameter data, hydrogen and oxygen stable isotope ratios of water can be used to characterize water sources. A list of the stable isotope samples collected and their results are reported in Table 3-7. The stable isotope data were collected to determine sources of perched water and to evaluate the flux from the vadose zone into the aquifer. Potential sources of water for perched wells in 2004 include discharge to the sewage lagoons, SRPA water leaking from raw water lines, and local precipitation (principally snowmelt). The conclusions and inferences drawn from the stable isotope study are indicative of the period over which samples were taken and could be different if the Big Lost River flows or there is an exceptional precipitation event. The analytical method used to determine the hydrogen and isotope ratios are described in Appendix B.

Table 3-7. Stable isotope results for perched water, groundwater, and source water samples.

		Stable Isotopes in Water		Stable Isotopes in Nitrate	
Station Name	Collection Date	$\delta^2\text{H}$ (‰ VSMOW)	$\delta^{18}\text{O}$	$\delta^{15}\text{N}$ (‰ Air-N, O-VSMOW)	$\delta^{18}\text{O}$
Perched Water					
33-2	09/23/03	-131.96	-17.31		
33-2	02/11/04	-134.27	-17.20	7.31	-4.16
33-2	07/12/04	-133.19	-16.98		
33-2	10/04/04	-132.60	-17.22		
33-3	09/23/03	-129.47	-16.48		
33-3	02/12/04	-131.26	-16.66	7.45	-7.3
33-3	07/14/04	-129.88	-16.69		
33-3	10/05/04	-129.00	-16.66		
33-4-1	09/17/03	-134.77	-17.48		
33-4-1	02/24/04	-134.04	-17.47	6.75	-6.56
33-4-1	07/14/04	-132.79	-17.33		
33-4-1	10/05/04	-135.10	-17.47		
37-4	09/10/03	-132.40	-16.96	14.07	-2.8
37-4	05/18/04	-131.60	-16.93	13.62	-2.78
37-4	07/12/04	-131.72	-17.11		
37-4	10/06/04	-131.50	-16.90		
55-06	09/16/03	-128.86	-16.76	8.21	2.76
55-06	02/19/04	-132.71	-17.18	7.35	-0.49
55-06	07/13/04	-133.82	-17.29		
55-06	10/11/04	-134.30	-17.36		
CS-CH	02/18/04	-135.88	-17.52	5.37	-6.44
MW-1-4	09/18/03	-132.35	-17.22	4.88	10.68
MW-1-4	05/25/04	-132.13	-17.18	4.46	10.38
MW-1-4	07/14/04	-132.86	-17.13		
MW-2	02/19/04	-129.26	-16.40	12.08	5.74
MW-2	07/13/04	-126.84	-15.96		
MW-2	10/06/04	-124.60	-15.56		
MW-5-2	09/15/03	-128.46	-16.52	6.77	-0.23
MW-5-2	02/18/04	-134.47	-17.32	5.87	1.4
MW-5-2	07/13/04	-134.09	-17.43		
MW-5-2	10/05/04	-130.10	-16.94		
MW-10-2	09/18/03	-129.56	-17.01		
MW-10-2	02/24/04	-132.55	-16.96	8.16	6.46
MW-10-2	07/12/04	-131.55	-16.96		
MW-10-2	10/04/04	-132.00	-16.99		
MW-15	10/11/04	-133.80	-17.39		
MW-15	10/11/04	-134.60	-17.40		

Table 3-7. (continued).

Station Name	Collection Date	Stable Isotopes in Water		Stable Isotopes in Nitrate	
		$\delta^2\text{H}$ (‰ VSMOW)	$\delta^{18}\text{O}$	$\delta^{15}\text{N}$ (‰ Air-N, O-VSMOW)	$\delta^{18}\text{O}$
MW-20-2	09/16/03	-127.60	-16.64		
MW-20-2	02/25/04	-132.66	-17.07	4.94	1.15
MW-20-2	07/13/04	-128.37	-16.51		
MW-20-2	10/06/04	-127.50	-16.31		
MW-24	09/07/03	-112.50	-12.15	28.99	-0.78
MW-24	02/25/04	-126.10	-15.57	18.82	-2.82
MW-24	07/15/04	-120.93	-14.31		
MW-24	07/15/04	-120.77	-14.23		
MW-24	10/26/04	-118.20	-13.68		
USGS 50	9/10/2003	NS	NS	5.32	7.85
USGS 50	5/18/2004	-134	-17.21	4.4	7.77
USGS-50	07/14/04	-133.4	-17.17		
USGS-50	11/05/04	-133.10	-17.20		
Groundwater					
ICPP-MON-A-230	04/14/04	-134.85	-17.34	7.75	1.06
MW-18-4	04/20/04	-135.25	-17.49		
LF3-08	04/05/04	-135.95	-17.61		
USGS-40	04/15/04	-135.90	-17.52		
USGS-41	04/15/04	-136.24	-17.64		
USGS-42	04/15/04	-135.86	-17.56		
USGS-47	04/06/04	-135.40	-17.65	4.02	6.95
USGS-48	04/13/04	-136.47	-17.64		
USGS-51	04/13/04	-136.94	-17.62		
USGS-52	04/14/04	-136.09	-17.68	7.4	2.93
USGS-57	04/08/04	-136.24	-17.53		
USGS-77	04/05/04	-136.62	-17.50	5.07	2.68
USGS-85	04/19/04	-135.79	-17.65		
USGS-112	04/06/04	-135.10	-17.58	5.17	2.33
USGS-121	04/12/04	-134.92	-17.56	6.33	-6.52
USGS-123	04/12/04	-135.50	-17.60	5.54	4.99

Table 3-7. (continued).

Station Name	Collection Date	Stable Isotopes in Water		Stable Isotopes in Nitrate	
		$\delta^2\text{H}$ (‰ VSMOW)	$\delta^{18}\text{O}$ (‰ VSMOW)	$\delta^{15}\text{N}$ (‰ Air-N, O-VSMOW)	$\delta^{18}\text{O}$ (‰ Air-N, O-VSMOW)
Source Waters					
Fire/Raw Water	09/10/03	-136.80	-17.67	7.32	-6.05
Fire/Raw Water	12/03/03	-135.43	-17.64		
Fire/Raw Water	02/25/04	-136.43	-17.69		
Fire/Raw Water	07/15/04	-136.51	-17.66		
Ponded Snowmelt #1	02/23/04	-156.87	-19.53		
Ponded Snowmelt #2	02/23/04	-142.67	-17.26		
Ponded Snowmelt #3	02/23/04	-155.53	-19.78		
Ponded Rain #A	10/28/04	-140.80	-18.98		
Ponded Rain #B	10/28/04	-139.30	-18.44		
Ponded Rain #C	10/28/04	-141.80	-19.01		
Ponded Rain #D	10/28/04	-143.60	-19.36		
Snow #1	02/23/04	-156.10	-19.43		
Snow #3	02/23/04	-152.62	-19.69		
Snow #2	02/25/04	-150.82	-19.38		
Potable Water Supply	09/10/03	-136.80	-17.64		
Potable Water Supply	12/03/03	-135.34	-17.63		
Potable Water Supply	02/25/04	-136.35	-17.68		
Potable Water Supply	07/15/04	-135.85	-17.68		
Sewage Lagoons	02/25/04	-135.11	-17.43		
Sewage Lagoons	09/11/03	-105.61	-11.04		
Sewage Lagoons	12/03/03	-118.30	-14.14		
Sewage Lagoons	07/15/04	-133.15	-17.41		
Steam Condensate ^a	12/03/03	-132.11	-17.01		
Steam Condensate ^b	02/25/04	-134.05	-17.37		
Steam Condensate ^c	02/25/04	-129.25	-16.55		
CPP-603 South Basin	11/23/04	-83.60	-6.40		
CPP-603 South Basin	11/23/04	-83.50	-6.44		
Drainage Ditch ^d	07/21/04	-135.65	-17.53		
a. East side of CPP-606					
b. West side of CPP-606					
c. Building CPP-637					
d. Water in ditch was fire water from Wells CPP-01 and CPP-02.					

The stable isotope data for oxygen and hydrogen used in the discussion below are expressed in conventional delta (δ) notation in per mil (‰, parts per thousand) difference in the ratio of the less abundant isotope to the most abundant isotope in a sample relative to the same ratio in a known reference standard Vienna Standard Mean Ocean Water (VSMOW) (Clark and Fritz 1997). The following equation is used:

$$\delta X_{\text{sample}} = [(R_{\text{sample}} - R_{\text{standard}}) / R_{\text{standard}}] \times 1000 \quad (3-1)$$

where

δX = the isotope of interest ($\delta^{18}\text{O}$, $\delta^{15}\text{N}$ or $\delta^2\text{H}$)

R = the ratio of $^{18}\text{O}/^{16}\text{O}$, $^{15}\text{N}/^{14}\text{N}$ or $^2\text{H}/\text{H}$.

3.3.1 Hydrogen and Oxygen Isotope Results

The $\delta^2\text{H}$ results for the perched water samples ranged from -112.5 to -135.88 ‰, while the $\delta^{18}\text{O}$ results ranged from -12.15 to -17.52 ‰. Most of the perched water samples had $\delta^{18}\text{O}$ values of -16 to -17.5 ‰ and $\delta^2\text{H}$ values of -131 to -135 ‰. A plot of $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values for the perched water and the SRPA samples is shown on Figure 3-4 along with the global meteoric water line (GMWL; Craig 1961) and a local meteoric water line (LMWL; USGS 2004). The global meteoric water line defines the

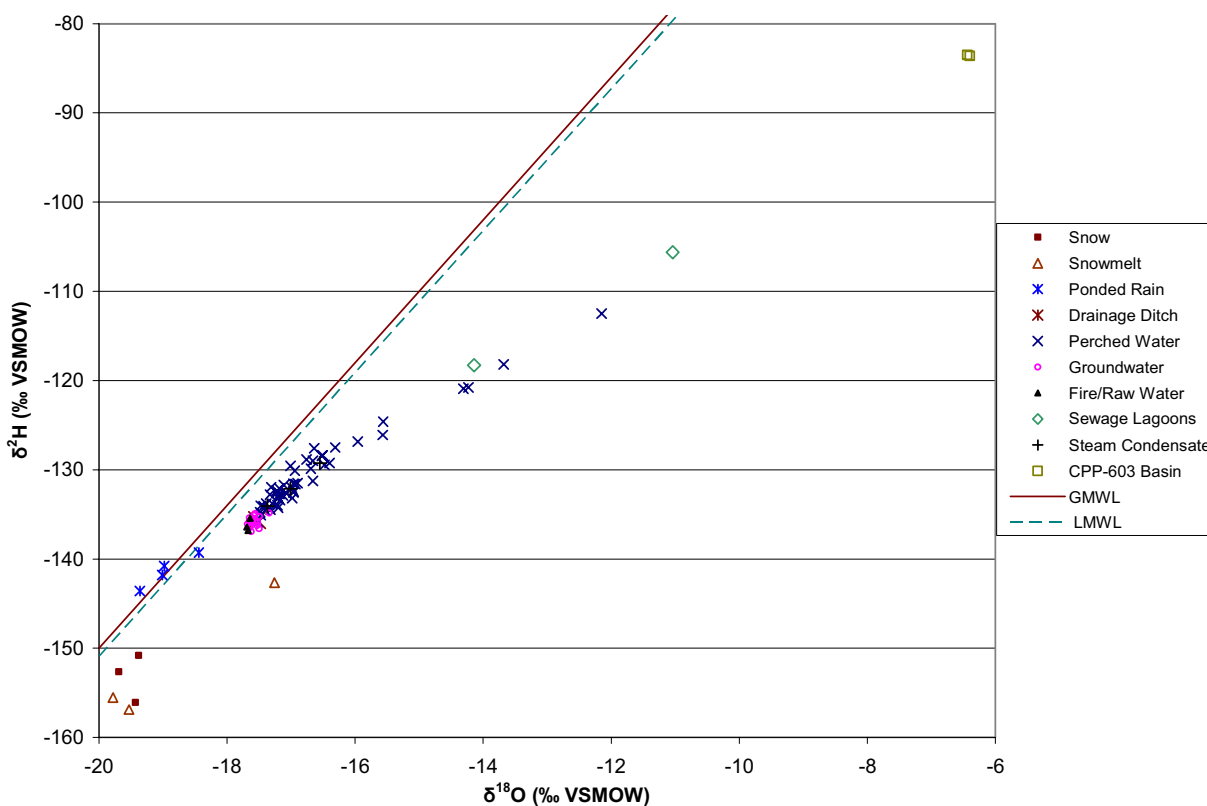


Figure 3-4. Oxygen and hydrogen isotope ratios for perched water, aquifer, and source water samples.

relationship between $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values in worldwide meteoric waters, but this line is actually a composite of many local or regional meteoric water lines. The global and local meteoric water lines are very similar (USGS 2004). The perched water samples plot below and to the right of the local meteoric water line (Figure 3-4). The perched water samples show a limited evaporative effect with higher $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values than water from the SRPA based on the values for fire/raw and potable water sources (Figure 3-4). In general, evaporation tends to produce $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values that fall along a line of lesser slope than the global or local meteoric water lines.

The $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values for various potential water sources are shown on Figure 3-4. The source that shows the most distinct signature is the water in CPP-603 basins that has a very pronounced evaporative signature. The fire/raw and potable water plot in tight cluster as expected because the source is the same. The snow and snowmelt (ponded water) samples have the lowest $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values of all the source samples and plot below the local meteoric water line. The next lowest $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values are associated with the ponded water samples collected in late October 2004. In contrast to the snow and snow melt sample, these samples plot on or near the local meteoric water line. Although not sampled, irrigation that is applied to lawns in INTEC should show an increase in $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values compared to that of SRPA water, due to evaporative effects.

The $\delta^{18}\text{O}$ and $\delta^2\text{H}$ results indicate that most of the perched wells plot near the values for the fire/raw and potable water supplies. None of the perched water samples plot in the area between the precipitation samples and the INTEC water supply (both raw and potable). The $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values for MW-24 plot in a range similar to the range of values for the sewage lagoons and shows the strongest evaporative signature of any of the perched wells.

3.3.2 Discussion of Hydrogen and Oxygen Stable Isotope Results

When comparing source water samples to water in the perched wells, it is important to consider how the source isotopic signature could be modified during migration from the point of release to the perched water bodies. The processes that could modify the isotopic signature include mixing with vadose zone water that has been partially evaporated, inputs of winter and summer precipitation, surface evaporation, and mixing of multiple source inputs.

The water from the SRPA is used as an example to show how a source water could be modified. The water samples from the SRPA near INTEC are shifted to the right of the local meteoric water line. This shift in $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values to the right of the meteoric water line for the groundwater samples in the SRPA could be due to mixing of infiltration with partially evaporated soil water in the area of recharge. In the case of a large recharge event, the shift from the meteoric water line may be minimal. It has been proposed that the shift in isotope values occurs during residence time in the upper meter of soil (DePaolo et al 2004). Another possible explanation for the shift in $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values to the right of the meteoric water line for the groundwater samples in the SRPA is that the $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values in the SRPA may be influenced by recharge from partially evaporated irrigation water in the Little Lost River valley near Howe, upgradient of the INTEC area. However, data to evaluate this alternative are not available. A third possibility is that the $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values for the SRPA beneath INTEC are more heavily influenced by late winter/early spring snowmelt since the $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values are within the range of February and April snow core measurements made at the Big/Little Lost Divide (USGS 2004). The $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values are close to the April values, or the high side to the range of snow core values. Any or all of the above factors could result in SRPA water falling to the right of the MWL, as observed.

Similarly, the $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values for infiltrating precipitation/snowmelt at INTEC could be modified by the same processes described above for SRPA water. A shift in isotope ratios would be

expected to occur as ponded water or snowmelt mixes with water in storage in the soil column. In addition, infiltrating precipitation could mix with water from other sources (raw water supply) to modify its signature. Partial evaporation of ponded water may also shift the isotope signature. One ponded snowmelt water sample appeared to show that effect. A possible example of the degree that the isotopic signature of infiltrating precipitation could be modified is given by a shallow well near the Reactor Technology Complex, formerly the Test Reactor Area, that had $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values of -16.66 and -133.07 ‰, respectively (DOE-ID 2004). A perched water location to evaluate the shift in the isotopic signature due only to the influence of infiltrating precipitation is not available near INTEC. Even though all perched water samples plot to the right of the SRPA samples, it cannot be concluded that infiltrating precipitation does not contribute to the formation of the perched water bodies. Partial evaporation of infiltrating snow or rainwater might cause this water to plot closer to the SRPA samples.

Although, winter precipitation is thought to be the major local contributor to recharge at the INL, the isotope signature of infiltrating precipitation could also be modified by infiltration of summer precipitation if a large storm event occurred. Summer precipitation was not sampled as part of this program because it is thought that the influence of summer precipitation on infiltration is minimal. Summer precipitation near INTEC was sampled in 2000 as part of the U.S. Geological Survey (USGS) program to develop a local meteoric water line. The limited results suggest that summer and early fall precipitation has considerably higher $\delta^{18}\text{O}$ (-9.84 to -13.43‰) and $\delta^2\text{H}$ (-65.6 to -120.8 ‰) values (USGS 2004). The influence from summer precipitation recharge would appear to be small or negligible given the high $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values for summer precipitation near INTEC (USGS 2004) and the much lower $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values for the perched water. Although not as significant as winter precipitation, summer precipitation might still be able to shift the isotopic signature of infiltrating precipitation.

Although the isotopic signature of infiltrating precipitation appears to be difficult to constrain, the mass of water infiltrating from winter precipitation does not appear to be enough to account for the observed perched water bodies based on the size of the ponded water bodies shown on Figure 2-5 and the amount of winter precipitation. The weather data collected at the Central Facilities Area weather station suggests that winter precipitation (December 2003 through March 2004) was approximately 1.41 in., with an average of 3 in. over the last 50 years (DOE-ID 2002). April and May had 1.83 in. of precipitation and there was over an inch precipitation in June and July 2004, but the much higher evapotranspiration rates limit the amount of infiltration that can occur after small summer rain events.

The above discussion on modifications of isotopic signature of infiltrating precipitation highlights potential problems associated with interpreting and comparing individual $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values from perched wells with source values. In contrast to infiltrating precipitation, water from a leaking underground fire line may only show a slight shift in isotopic signature if the leak is of sufficient size to displace previous pore moisture and constant. Water infiltrating from facility practices (discharge of fire hydrant water) may show some shift in isotopic signature that could be related to the duration and frequency (time of year) of the discharge. The collection of time series isotope data allows for the examination of the relative changes in isotope signatures with changes in water levels and allows for the evaluation of multiple water sources.

On the basis of the degree of variation in $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values, the perched wells can be divided into two groups. The Group "A" wells are characterized by $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values that were relatively constant over the sampling period (less than two times the analytical precision of $\pm 0.2\text{‰}$ or within a range of 0.4 ‰ for $\delta^{18}\text{O}$ and $\pm 2\text{‰}$ or within a range of 4 ‰ for $\delta^2\text{H}$) (Figure 3-5). The Group A wells include Well 37-4, Well 33-4-1, Well 33-2, Well MW-1-4, Well USGS-050, and Well MW-10-2. The Group "B" wells have $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values that show variations greater than 0.4 ‰ $\delta^{18}\text{O}$ values and 4 ‰ for $\delta^2\text{H}$ values over the sampling period (Figure 3-6). The Group B wells include Well MW-24, Well MW-20-2,

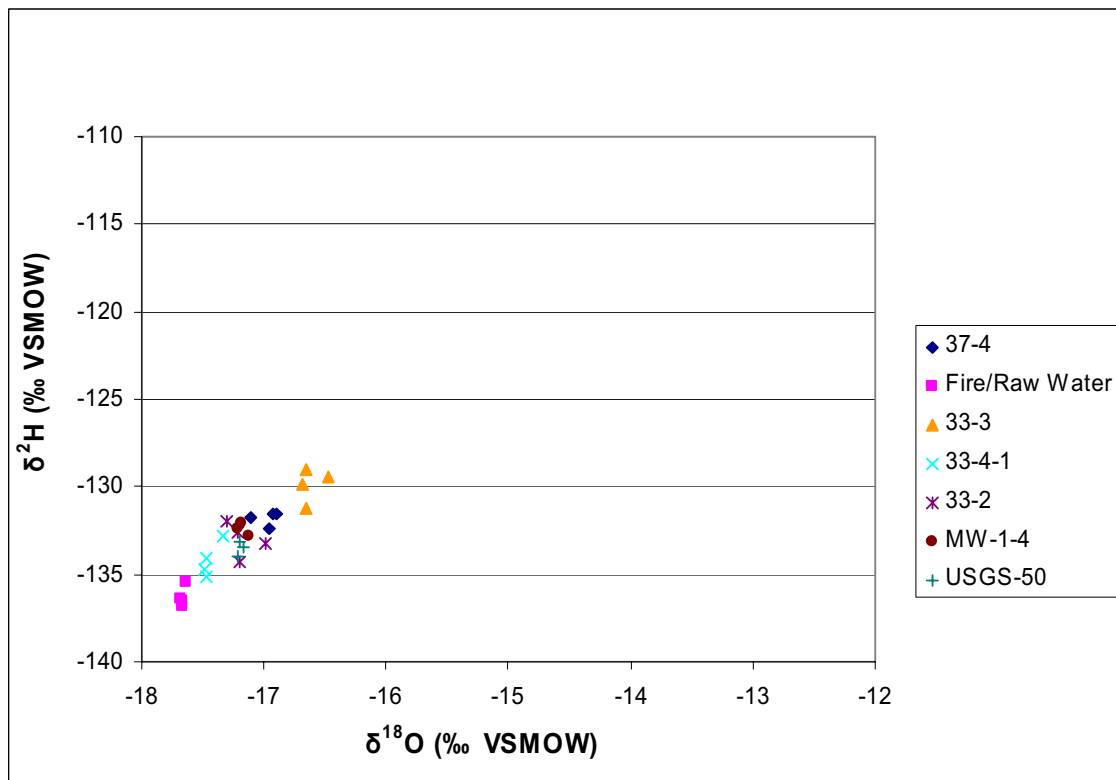


Figure 3-5. Group A wells showing small temporal variations in stable isotopic composition.

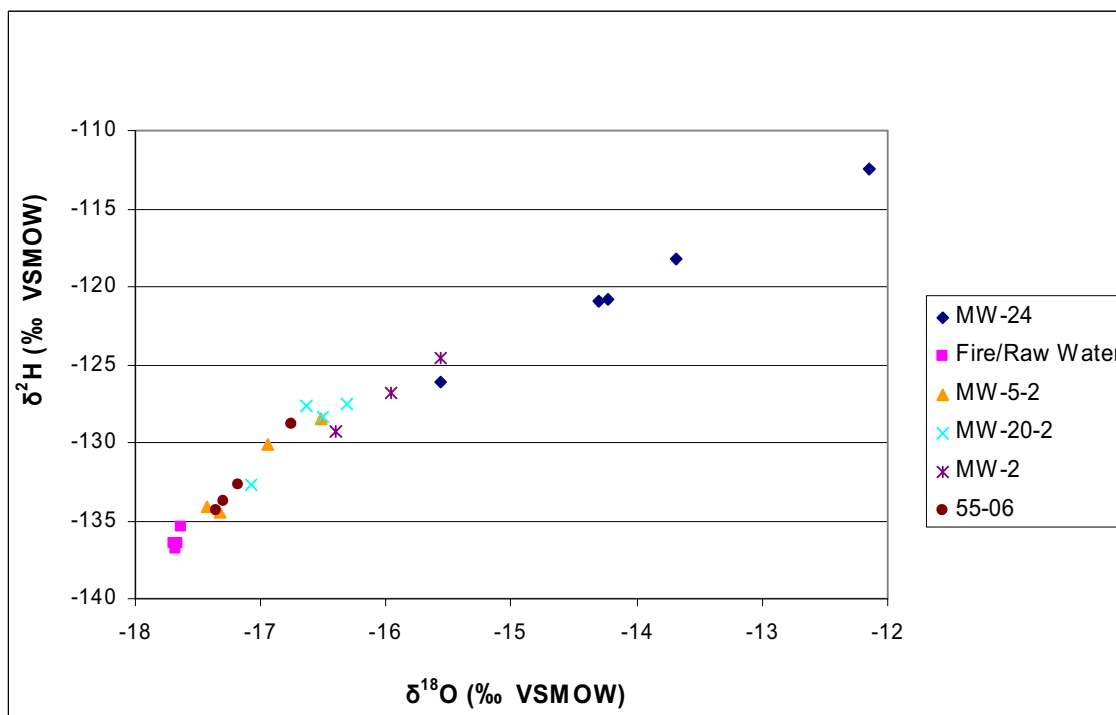


Figure 3-6. Group B wells showing large temporal variations in stable isotopic composition.

Well MW-5-2, Well MW-2, and Well 55-06. Variation in isotope signature was not evaluated for Well CS-CH and Well MW-15, because only a single sample was taken from these wells.

The Group A perched wells generally plot near the values for the fire/raw and potable water supply (Figure 3-5). The consistent $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values for the other Group A wells implies either a constant and consistent source or a low recharge rate. A constant and/or consistent source could be leakage from facility infrastructure. A low recharge rate would imply that these wells are below the “critical depth” or the depth at which isotope variation is less than 2 times the analytical precision (Clark and Fritz 1997). The critical depth is the depth below which seasonal variations or impacts from multiple sources are smoothed out so that a nearly constant isotopic signature is achieved. The lack of variation in the $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values for the deep perched Group A wells, Well USGS-050 and Well MW-1-4, could be because these wells are below the critical depth.

Group B wells appear similar in composition to the fire/raw and potable water supply, but exhibit a more pronounced seasonal evaporative signature (Figure 3-6). Of the Group B wells, Well MW-24 located next the sewage treatment infiltration lagoons shows the most pronounced seasonal changes with an increase in the $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values in the warmer months due to evaporative effects on the infiltration from the sewage lagoons. Well MW-20-2 shows a distinct winter rise in water levels with a corresponding drop in $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values. Well MW-5-2 shows a decrease in the January through July period followed by an increase in the July to October period. In contrast to oscillating $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values for the other Group B wells, Well 55-06 shows a steady decrease in $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values while Well MW-2 shows a steady increase in $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values.

3.4 Stable Isotope Ratios of Nitrate

The goals of the nitrogen isotope study were to identify (1) the nitrate contributions of the sewage treatment plant to the perched water and the aquifer beneath INTEC, (2) the impacts of non-sewage anthropogenic sources of nitrate such as nitric acid spills and leaks, and (3) the source of elevated nitrate concentrations in the SRPA downgradient of the INTEC. The analytical method used to determine the nitrogen and oxygen isotope ratios in nitrate are described in Appendix B.

3.4.1 Nitrogen and Oxygen Isotope Ratio Results

The $\delta^{15}\text{N}$ results for the perched water samples ranged from +4.4 to +28.99 ‰, while the $\delta^{18}\text{O}_{\text{nitrate}}$ results ranged from -7.3 to +10.68 ‰ (Table 3-7). In order to examine the potential sources of nitrate contamination, the $\delta^{15}\text{N}$ values were plotted versus the $\delta^{18}\text{O}$ values for nitrate (Figure 3-7). The plot of $\delta^{15}\text{N}$ values versus the $\delta^{18}\text{O}_{\text{nitrate}}$ values shows three possible end members or sources of nitrate (Figure 3-7). The first source is represented by high $\delta^{15}\text{N}$ values (+14 to +28 ‰) with $\delta^{18}\text{O}$ of nitrate from 0 to -3. Natural background values are represented by the upgradient Well USGS-121 and the raw water supply for INTEC, and are represented by nitrogen isotope ratios of 6 to 8 ‰ and $\delta^{18}\text{O}$ of nitrate of -6 to -7 ‰. A third source of nitrate is represented by lower $\delta^{15}\text{N}$ values (4 to 5 ‰) and high $\delta^{18}\text{O}_{\text{nitrate}}$ values of 7 to 10 ‰. The majority of perched water and aquifer samples plot along a trend from the background (USGS-121 and INTEC raw water supply) $\delta^{15}\text{N}$ and the $\delta^{18}\text{O}_{\text{nitrate}}$ values to the $\delta^{15}\text{N}$ and the $\delta^{18}\text{O}$ values for MW-1-4.

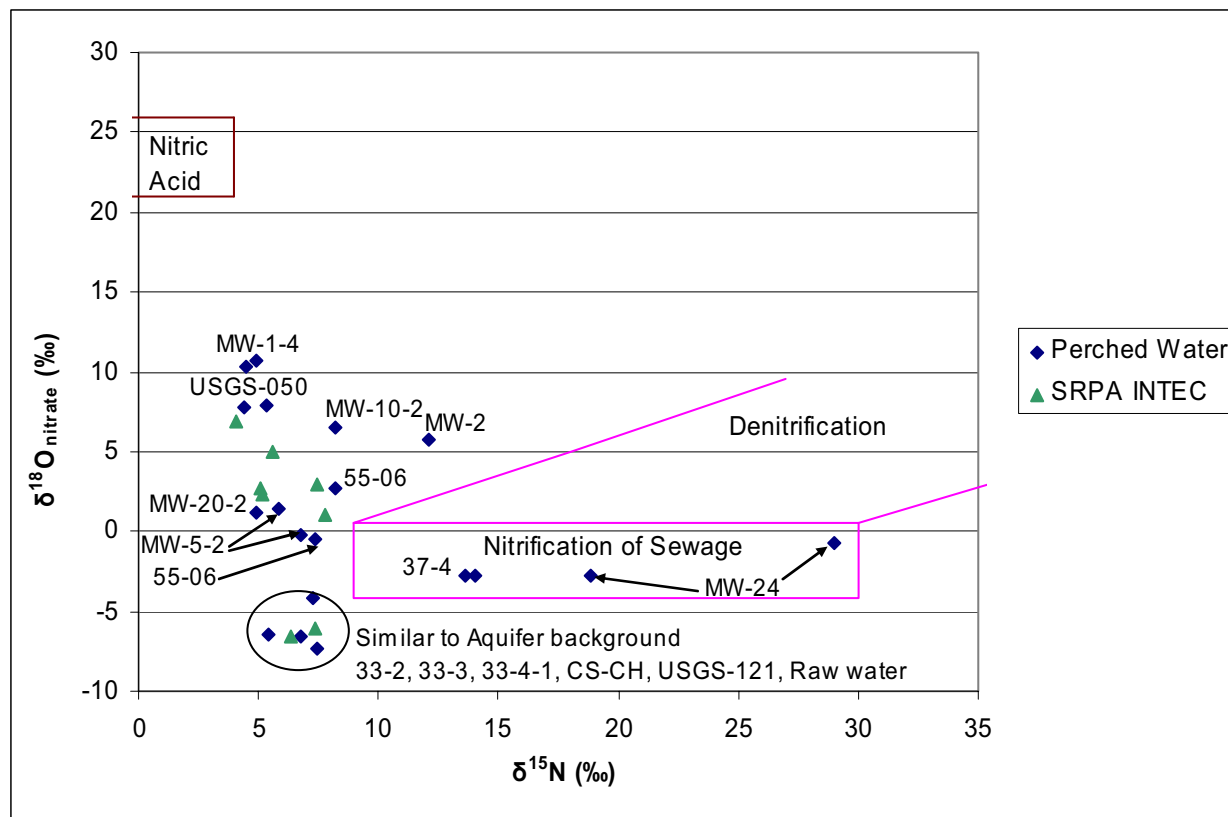


Figure 3-7. Nitrogen and oxygen stable isotope ratios in nitrate.

3.4.2 Discussion of Nitrogen and Oxygen Isotope Results

The nitrate results are discussed with respect to the potential sources of nitrate: sewage effluent, manufactured sources (for example nitric acid), or natural sources. The $\delta^{18}\text{O}_{\text{nitrate}}$ can be used in combination with $\delta^{15}\text{N}$ data to better determine the source of the nitrate. The $\delta^{15}\text{N}$ of commercially produced nitrate (such as fertilizers) should be 0 ± 4 ‰, because the nitrogen used in commercial processes is drawn from the atmosphere and isotopic fractionation does not occur because of the complete or nearly complete conversion. The $\delta^{15}\text{N}$ range for nitrification of sewage is shown as 9 to 30 ‰ in Figure 3-7 and was expanded from the typical range of 9 to 21 ‰ (Clark and Fritz 1997) based on a sample from MW-24 near the INTEC sewage treatment facility. Nitrate from man-made nitric acid, such as from the tank farm, would derive oxygen from the atmosphere with a $\delta^{18}\text{O}_{\text{nitrate}}$ of +23.5 ‰ (Amberger and Schmidt 1987; Bolhke et al. 2003). The $\delta^{18}\text{O}_{\text{nitrate}}$ of nitric acid has been determined to be 21 to 26 ‰ and is similar to the value for atmospheric $\delta^{18}\text{O}$ of +23.5 ‰ (Bohlke et al. 2003). In contrast, the nitrate formed from the biologically mediated oxidation of reduced nitrogen species, ammonia for example, derives two of its three oxygen atoms from the local water and one from air (Hollocher 1984; Amberger and Schmidt 1987; Clark and Fritz 1997).

The $\delta^{18}\text{O}_{\text{nitrate}}$ derived from the nitrification of sewage can be expressed by the following equation:

$$\delta^{18}\text{O}_{\text{nitrate}} = 2/3 (\delta^{18}\text{O}_{\text{water}} + \epsilon_{\text{water}}) + 1/3(\delta^{18}\text{O}_{\text{O}_2} + \epsilon_{\text{O}_2}). \quad (1)$$

The water from the SRPA in the vicinity of INTEC has $\delta^{18}\text{O}$ values of -17 to -18 ‰ (Table 3-7) (DOE-ID 2003a; USGS 1999). Effluent from the INTEC sewage treatment lagoons shows a range of $\delta^{18}\text{O}$ values from -12 to -17 ‰. Nitrate derived from nitrification of sewage should have $\delta^{18}\text{O}_{\text{nitrate}}$ values between 0.16 and -3.5 ‰, based on $\delta^{18}\text{O}$ values of -12 to -17 ‰ for water, the above equation, and the assumption that isotope fractionation during water (ϵ_{water}) and O_2 (ϵ_{O_2}) incorporation is negligible. Two wells, Well MW-24 and Well 37-4 (Figure 3-7), located near the sewage treatment lagoons at INTEC fit this equation very well when using $\delta^{18}\text{O}$ values for the water in these wells. The high $\delta^{15}\text{N}$ values for MW-24 and 37-4 and $\delta^{18}\text{O}_{\text{nitrate}}$ values indicate that the nitrate in these wells is derived primarily from sewage effluent. In addition, Well 33-2 also fits this equation when using the $\delta^{18}\text{O}$ values for the water in this well, but this well does not show sewage impacts based on its $\delta^{15}\text{N}$ value.

The elevated $\delta^{15}\text{N}$ value for MW-24 in September 2003 was probably due to the loss of ammonia prior to infiltration. This would account for the lower nitrate concentration in MW-24 in September and the higher $\delta^{15}\text{N}$ value. As discussed previously, MW-24 had a strong evaporative signature based on $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values for the water. In addition to MW-24, both samples from 37-4 are within the area for nitrification of sewage (Figure 3-7). However, no wells plotted within the area that is indicated by denitrification of sewage nitrate based on the denitrification trends determined by Bottcher et al. (1995). The process of denitrification tends to increase the $\delta^{15}\text{N}$ and the $\delta^{18}\text{O}_{\text{nitrate}}$ at a rate of 2:1. The $\delta^{15}\text{N}$ values and the $\delta^{18}\text{O}$ values for nitrate in most INTEC perched wells are inconsistent with a sewage source.

The $\delta^{18}\text{O}_{\text{nitrate}}$ value for most wells does not appear to fit Equation 1, nor do the perched wells plot within the area that would indicate nitrification and denitrification of sewage (Figure 3-7). Although the $\delta^{15}\text{N}$ value for the SRPA (background) is similar to most of the values in the perched wells, a natural source of the nitrate is unlikely for most wells, because the background and probably natural $\delta^{18}\text{O}_{\text{nitrate}}$ is -6 ‰ compared to $\delta^{18}\text{O}_{\text{nitrate}}$ values of 2 to 10 ‰ for most of the perched wells and because nitrate concentrations in perched water are significantly elevated above that in the SRPA. Three perched wells, Well CS-CH, Well 33-4-1, and Well 33-3, show $\delta^{18}\text{O}_{\text{nitrate}}$ values of -6 ‰ or less and are similar to the background aquifer Well USGS-121 and the INTEC production well located upgradient of INTEC. USGS-121 does not appear to be affected by nitrate contamination from INTEC. The background SRPA well and three perched wells have $\delta^{18}\text{O}_{\text{nitrate}}$ values that are lower than would be predicted based on Equation 1. Three possible explanations that could account for the lower $\delta^{18}\text{O}_{\text{nitrate}}$ values than expected based on Equation 1 are: (1) water that infiltrates in the spring has a lower $\delta^{18}\text{O}$ value of -18 to -20 ‰, and this water forms nitrate in natural or background conditions; (2) nitrate formation occurs through a nonbiological process rather than by a biological process as described in Equation 1; and (3) the $\delta^{18}\text{O}$ of the soil gas may be different than atmospheric values. In contrast to this investigation, most other studies have reported higher $\delta^{18}\text{O}$ values in nitrate than calculated from Equation 1 (Mayer et al. 2001; Aravena et al. 1993). Although the cause of the lower than expected $\delta^{18}\text{O}$ values is unknown, the $\delta^{18}\text{O}$ values in nitrate in the background well are distinct from other potential sources. Consequently, background or natural concentrations appear to be able to explain nitrate concentrations in only Well CS-CH, Well 33-4-1, Well 33-3, and perhaps Well 33-2.

Another potential source of nitrate contamination is nitric acid spills or leaks. Although the perched water samples have $\delta^{18}\text{O}_{\text{nitrate}}$ values much lower than that expected for nitric acid, 21 to 26 ‰, the $\delta^{18}\text{O}_{\text{nitrate}}$ from a nitric acid spill/disposal could reflect equilibration with local water. If the mole fraction of HNO_3 in the original solution is greater than 0.4 , then the exchange rate between nitric acid and water is high (hours to days for equilibrium), but the exchange rate is essentially not measurable at lower concentrations unless solutions also contain amounts of intermediate nitrogen-oxygen compounds like nitrite (Bolhke et al. 2003). If equilibration with local water did occur, then the $\delta^{18}\text{O}_{\text{nitrate}}$ from nitric

acid would be based on the nitrate concentration in the original solution and the fractionation factor for nitrate-water. A fractionation factor for $\delta^{18}\text{O}_{\text{nitrate}}$ of 1.0215 was determined for equilibration of acid with water at 22°C (Bohlke et al. 2003). If this factor is applied to perched water with $\delta^{18}\text{O}$ values of -16 to -18 ‰, then $\delta^{18}\text{O}_{\text{nitrate}}$ values of 3 to 5 ‰ are calculated for nitrate equilibrated with local water. The calculated range for equilibrium of nitric acid with local water is close to the observed $\delta^{18}\text{O}$ values for INTEC perched water and aquifer samples. A good deal of uncertainty is associated with the calculation of the $\delta^{18}\text{O}_{\text{nitrate}}$ for nitrate from nitric acid, because the methods used to neutralize the nitric acid solutions are uncertain. Because of that uncertainty, $\delta^{18}\text{O}_{\text{nitrate}}$ from nitric acid that has equilibrated or partially equilibrated with local water could fall within the range of 3 to 23 ‰. This $\delta^{18}\text{O}$ range is higher than the expected values for sewage nitrate that has not undergone denitrification and much higher than background $\delta^{18}\text{O}_{\text{nitrate}}$ values (Figure 3-7).

The deep perched Wells USGS-50 and MW-1-4 have $\delta^{18}\text{O}_{\text{nitrate}}$ and $\delta^{15}\text{N}$ values that appear to indicate a manufactured source of nitrate. These two deep perched water wells do not appear to be affected by the INTEC sewage lagoons based on nitrogen and oxygen isotope ratios in nitrate and oxygen and hydrogen isotope ratios in water.

The perched Wells MW-10-2, MW-20-2, MW-5-2, MW-2 and 55-06 have $\delta^{18}\text{O}_{\text{nitrate}}$ and $\delta^{15}\text{N}$ values that suggest multiple nitrate sources. Wells MW-20-2, MW-5-2, and 55-06 plot between the values for MW-1-4 and the background SRPA values. This suggests that mixing of a background source and manufactured source could explain the nitrate concentrations in these wells. Well MW-2 and perhaps MW-10-2 may reflect a limited amount of denitrification because these wells appear to be shifted from the trend line between MW-1-4 and background. Although MW-2 appears to have an $\delta^{15}\text{N}$ value that could indicate sewage contamination, the $\delta^{18}\text{O}_{\text{nitrate}}$ value is not consistent with a sewage source (Figure 3-7).

Aquifer Wells USGS-047 and USGS-123 have $\delta^{18}\text{O}_{\text{nitrate}}$ and $\delta^{15}\text{N}$ values that are consistent with the values for the deep perched wells and would suggest the major source of nitrate in these wells is a manufactured source. Wells USGS-052, USGS-77, USGS-112, and ICPP-MON-A-230 plot in an area on Figure 3-7 that could reflect mixing of background and a manufactured source of nitrate. None of the aquifer wells appear to show a strong influence from the sewage lagoons.

3.5 Discussion of Perched Water Sources

The geochemical and water level monitoring results are discussed on an individual well basis to address potential sources of water in the perched wells. The perched water sources are discussed using data collected during the geochemical study (2003–2004).

Although, the $\delta^{18}\text{O}_{\text{nitrate}}$ and $\delta^{15}\text{N}$ values indicate that the source of nitrate in 37-4 is sewage, the $\delta^2\text{H}$ and $\delta^{18}\text{O}$ results for water indicate that the sewage treatment lagoons are not the primary source of this water, because the water in this well is not consistent with the evaporative $\delta^2\text{H}$ and $\delta^{18}\text{O}$ signature observed in MW-24. In addition, the chloride data for 37-4 are too low to be consistent with the current effluent in the sewage treatment lagoons. Also, the nitrate concentrations in 37-4 are equal to or greater than the values for MW-24 in all but one sample suggesting that nitrate concentrations in 37-4 are not the results of dilution with a small amount of infiltration from the sewage lagoons. Historical data indicate that waters released from the sludge dewatering pit of the old sewage treatment plant (CPP-715) was disposed in a trench in the vicinity of Well 37-4 (DOE-ID 1999). This is site CPP-37B shown on Figure 2-4. The water source at 37-4 could be leaking raw water lines or infiltrating precipitation or a combination of both. The sample from July 2004 appears to show evidence of precipitation infiltration

because the concentration of metals, anions and specific conductance decrease and the $\delta^{18}\text{O}$ value of the water decreases. However, the downhole electrical conductivity measurements (see Appendix A) suggest that the pulse of low conductivity water (infiltrating precipitation) was short in duration. The short duration would suggest the migration of a wetting front through the vadose zone. A small snowmelt pond was observed near Well 37-4 in the spring of 2004 (Figure 2-5). The short pulse of infiltrating water implies that there are multiple sources of water for this well including infiltration of precipitation and perhaps leakage from a fire line that runs near this well.

Well 33-4-1 shows relatively consistent $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values that indicate a consistent water source. The relative and absolute concentrations of the common ions are similar to SRPA water (fire/raw and potable water supply). The $\delta^{15}\text{N}$ and $\delta^{18}\text{O}_{\text{nitrate}}$ isotope ratios are similar to background for the SRPA near INTEC. There was a nearly 3-ft drop in water level between mid-May and the July sampling event, but analytical parameters showed only modest variations. The dominant source of water for this well is probably leaking facility raw/potable water lines or discharges.

Well 33-3 shows relatively consistent $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values indicating a consistent water source. The chloride concentrations are too high to be from service waste water. The common ion signature indicates significant brine impacts (Figure 3-2; Tables 3-3 and 3-4). Well 33-3 is located near the CPP-736 brine storage tank (see Figure 2-4 for the location of the brine storage tank). The source of the contamination is probably the brine tank (CPP-736), the brine pumping building (CPP-1610) or leakage from the brine pipeline from the tank to building CPP-606. Elevated chloride and dissolved metals concentrations have been present in the 33-3 since 1994. Water in the brine pit (tank) that is saturated with respect to sodium chloride, water leaking from the tank, lines, or pump building is most likely mixing with a dilute water that has an isotopic signature shifted (partially evaporated) compared to raw water.

Although Well 33-2 shows relatively consistent $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values indicating a consistent water source, water level dropped more than 4 ft between the first and second sampling events. The well shows some elevated chloride and sodium concentrations that could indicate salt impacts (Figure 3-2; Tables 3-3 and 3-4). Strontium-90 concentrations tend to decrease with decreasing water-level. Chloride appears to decrease with decreasing water level and increase with increasing water level. This would suggest a higher chloride and $\delta^{18}\text{O}$ value for water infiltrating into the well in the October/November timeframe. This could possibly represent infiltrating precipitation, because precipitation would be expected to have lower $\delta^{18}\text{O}$ values, and one of the ponded water samples had high chloride concentrations. Although the $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values suggest a single source of water, the chloride data suggests multiple water sources. The nitrogen/oxygen data suggest a natural or background source that is consistent with infiltrating precipitation.

The water level and stable isotope data suggest at least two sources of water for Well MW-20-2. Well MW-20-2 shows a pronounced increase in water level from September until about April, and then a decrease back to the original level. The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values for the sample collected when the water level increased indicates a water source with lower $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values than the water that was in the well prior to the increase in the water level. This source could be leakage from the fire/raw supply or infiltration of precipitation. During the period from September to the end of April, the flow in the fire lines is increased from 5 to 25 gpm for freeze protection (DOE-ID 2003c). Another possible explanation for the rise in water levels could be the result of discharge of snowmelt from the roof of CPP-699 at a downspout located a few feet north of this well. If a fast flow path exists, then this could be the source of the water responsible for the increase in water-level. This would also be consistent with the major ion and contaminant data that show small variability and a decrease in the $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values. The small

decrease in $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values could occur even if the water source was leaking fire water lines. This is because the increased loss rate in the winter months would be similar in effect to a large recharge event with a short residence time in the vadose zone. The increased leak rate or supply of water would initially mix with and then displace pore space water leading to an isotopic composition more closely resembling the source.

The deep Well MW-1-4 shows little variation in the stable isotope ratios, major ion data, and contaminant data. As discussed previously, the consistent concentrations and stable isotope ratios could either indicate a constant stable source or indicate that the well is located below the depth at which seasonal or water source variations are discernable. Although there is a nearly 4-ft increase in water levels between the May and July sampling event, parameter values remain nearly constant. The long-term contaminant data indicate a consistent downward trend for tritium and strontium-90. Even though the hydrogen and oxygen isotope ratios are consistent with leaks from facility infrastructure, infiltrating precipitation cannot be ruled out as a contributing source.

Like MW-1-4, the deep Well USGS-050 shows little variation in the stable isotope ratios and major ion chemistry. The tritium and strontium-90 data indicate a consistent downward trend in concentration (DOE-ID 2003a). The consistent major ion concentrations and stable isotope ratios could either indicate a constant water source or indicate that the well is located below the depth at which seasonal and water source variations are discernable. Even though the $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values are consistent with leaks from facility infrastructure (fire/raw or potable), infiltrating precipitation cannot be ruled out as a contributing source. Although the relative major ion concentrations are similar to data for MW-24 located next to the sewage lagoons (see Figure 3-1), the relatively high $\delta^{18}\text{O}_{\text{nitrate}}$ and low $\delta^{15}\text{N}$ values indicate a manufactured source of nitrate rather than a sewage source. The relative major ion concentrations are also similar to 33-2 located near USGS-050, and a recharge water source in this area is probable.

Well MW-10-2 shows consistent water levels, major ion concentrations (except for one nitrate value), and $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values. The water source could be leakage from the fire/raw or potable water supply or infiltration of precipitation. The concentrations of major ions are much greater than that of the fire/raw and ponded winter precipitation, but if recharge was low, that could allow for more dissolution and an increase the dissolved solids. A low recharge rate is suggested by the several days that it takes for water levels to recover after a sampling event (see graphs in Appendix A). Because the $\delta^{15}\text{N}$ value and the $\delta^{18}\text{O}_{\text{nitrate}}$ are consistent with a manufactured source (nitric acid), influence from the sewage lagoons is thought to be negligible.

Well MW-2 probably has multiple sources of water. The water level data show a dramatic rise in water levels occurring in late November 2003. Two potential seasonal influences are steam condensate discharge and the increased leakage in the fire lines due to increased flow in the lines. The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ value for the sample collected in February 2004 is more consistent with values from the steam condensate, but the relative change in $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values could not be evaluated because a sample was not collected in September 2003. The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values for this well would be consistent with infiltration from the sewage lagoons mixing with fire/raw water, potable water supply, or infiltration of precipitation (Figure 3-6). The $\delta^{15}\text{N}$ value is consistent with a sewage source, but the $\delta^{18}\text{O}_{\text{nitrate}}$ is not consistent with a sewage source even after accounting for the possible effects of denitrification. The $\delta^{15}\text{N}$ and the $\delta^{18}\text{O}_{\text{nitrate}}$ values are consistent with a source (nitric acid) that has undergone some degree of denitrification. The oxidizing water in MW-2 is not favorable for denitrification. But, denitrification could have occurred along a migration path prior to reaching this well and subsequently mixed with oxidizing water. Because the $\delta^{18}\text{O}_{\text{nitrate}}$ value is inconsistent with a sewage source, the water source could be a

mixture of steam discharge, fire water, and infiltrating precipitation. Alternatively, one of the water sources could be a source other than those sampled during the geochemical study.

Multiple water sources are indicated for Well MW-5-2 on the basis of the stable isotope data and electrical conductivity data. The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values show a trough pattern for the four samples collected from this well suggesting multiple water sources. The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values for this well decrease in value over the winter and then increase in the fall. The increase in $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values in the fall coincides with an increase in conductivity and contaminant concentrations. The low $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values and major ion concentrations are consistent with fire/raw water, potable water supply, or infiltration of precipitation. The higher $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values and conductivity values are similar to water from the sewage lagoons. However, the $\delta^{15}\text{N}$ value and the $\delta^{18}\text{O}_{\text{nitrate}}$ value are consistent with a manufactured source (nitric acid) rather than a sewage source. This high conductivity water is not typical of the source waters sampled during the geochemical study and could represent another water source. The source may be the result of a steam leak discovered near CPP-1608 some 200 ft south of MW-5-2. The leaking steam line was reportedly shut off in the fall of 2004, and the line is now being dug up and cut/capped.

Like MW-5-2, Well 55-06 shows indications of multiple water sources. Although a significant spike in water elevation occurs, the strontium-90 concentration does not seem to change along with the water levels. In contrast, the $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values show a trend of decreasing values and chloride, and nitrate shows a trend of decreasing concentrations. The trends of decreasing $\delta^2\text{H}$, $\delta^{18}\text{O}$ and chloride and nitrate concentrations are consistent with leakage from the fire/raw water, potable water supply, or infiltration of precipitation replacing water from another source. Steam condensate could be the source of the higher $\delta^2\text{H}$ and $\delta^{18}\text{O}$ in 55-06; however, steam condensate water would need to dissolve a considerable amount of solids because the steam condensate is very dilute. The sewage lagoons fit the major ion composition of this well better, and $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values are within the range for the sewage lagoons. However, the $\delta^{15}\text{N}$ and $\delta^{18}\text{O}_{\text{nitrate}}$ values are not consistent with a sewage source.

Although not in the tank farm area, Well CS-CH was sampled to evaluate the source of nitrate in the well and the source of the water. The relative major ion concentrations are not consistent with any water source sampled as part of the geochemical study (Figure 3-1). The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values for the water are consistent with leaks from raw/potable water supply. Infiltrating precipitation cannot be ruled out as the source of the water or a combination of raw/potable and infiltrating precipitation. The $\delta^{15}\text{N}$ value and the $\delta^{18}\text{O}_{\text{nitrate}}$ are similar to those in the background aquifer well and raw water supply.

The source of the sudden appearance of water in MW-15 was also investigated. The $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values of the water and the major ion data both favor leaking facility pipelines (fire/raw or potable water) or a discharge of facility water as the source. The CPP-603 basins are not the water source because of the large differences in $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values and major ion concentrations. The CPP-603 basin water shows a strong evaporative signature with the highest $\delta^2\text{H}$ and $\delta^{18}\text{O}$ values of all the samples collected.

3.6 Water Flux from the Vadose Zone to the Aquifer

Nitrogen and oxygen isotope ratios in nitrate were used to evaluate the flux of water from the vadose zone into the aquifer. Groundwater samples were collected from SRPA Wells USGS-121, USGS-47, USGS-112, USGS-77, USGS-123, USGS-52, and ICPP-MON-A-230 to evaluate potential impacts on the SRPA from contaminant flux from the tank farm area or the sewage treatment lagoons. USGS-047 and USGS-123 had $\delta^{15}\text{N}$ values and the $\delta^{18}\text{O}_{\text{nitrate}}$ values similar to deep perched Wells MW-1-4 and USGS-050, but most aquifer wells had $\delta^{15}\text{N}$ and the $\delta^{18}\text{O}_{\text{nitrate}}$ values that tended to plot between a manufactured source and background (USGS-121) (Figure 3-7). This would suggest that

the influence of the sewage treatment lagoons is very small beneath INTEC. This would also suggest that precipitation and water from leaking infrastructure or discharged by facility practices are the primary means of transporting nitrate and other contaminants to the aquifer. Consequently, elevated nitrate concentrations in the SRPA are probably due in part to downward migration of water from the tank farm area.

The flux from the vadose zone can also be evaluated using the $\delta^{18}\text{O}$ and δD values for water from the aquifer wells. The $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values in wells located beneath INTEC are not shifted from the upgradient Well USGS-121 or the INTEC production wells to a significant degree (more than two times the analytical precision of 0.2 ‰ for $\delta^{18}\text{O}$ and 4 ‰ for $\delta^2\text{H}$). An insignificant change in $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values is expected if the flux from the vadose zone is low or if the flux from the vadose zone has $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values similar to that of the deep perched Wells MW-1-4 and USGS-050. Taking into consideration the strong evaporative signature of the infiltration from the sewage lagoons, the lack of a distinct shift toward higher $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values in the aquifer wells beneath INTEC indicates that infiltration from the sewage treatment lagoons is small compared with the underflow in the SRPA.

The hydrogen and oxygen isotopic data appear insufficient to evaluate flux from the vadose zone at INTEC. Anion data may be able to provide a better means of evaluating flux from the vadose zone based on elevated chloride, nitrate, and sulfate concentrations in wells beneath INTEC. Sampling for anions (chloride, sulfate, and nitrate) in the aquifer upgradient and underneath INTEC could provide data to evaluate the effectiveness of remedies aimed at reducing infiltration. The pattern or the presence of elevated anion concentrations, principally nitrate, chloride and sulfate, in the SRPA beneath INTEC could be used to evaluate the vadose zone flux into the aquifer. If water infiltration sources are successfully removed or reduced, the concentrations of these parameters should also decrease to background levels.

3.7 Summary and Conclusions

Identification of water recharge sources is important in reducing the flux of contaminants toward the aquifer beneath INTEC, as required by the remedy for OU 3-13 Group 4. The water quality and stable isotope data indicate that the perched water beneath the northern part of INTEC originates from several different sources. These recharge sources include intentional discharge of water to unlined ditches, leakage from underground pipelines, and infiltration of rain and snowmelt. Precipitation by itself does not appear to account for all of the observed perched water. However, the contribution from precipitation is difficult to evaluate because evaporation changes the oxygen and hydrogen isotope ratios during downward migration of the water from the surface to the perched water zones. In addition, the influence of precipitation varies from year to year, depending on the amount of annual precipitation, snow pack buildup and spring melt conditions. The relatively low winter precipitation in 2003 to 2004 during the geochemical study may be a contributing factor to the apparent small influence of precipitation on perched water recharge.

The stable isotope and major ion water quality data suggest that a combination of leaks from underground pipelines and water intentionally discharged to the ground accounts for much of the perched water. However, even prior to their decommissioning in December 2004, the sewage treatment plant infiltration trenches appear not to have constituted the principal source of the perched water beneath the northern part of INTEC. Rather, water leaks and discharges inside the northern portion of the facility appear to be the primary sources recharging the perched water.

Based on nitrogen and oxygen isotope ratios, the elevated nitrate concentrations observed in the SRPA beneath INTEC appear to result from downward migration of nitrate from the vadose zone near

the tank farm. The elevated nitrate in the vadose zone appears to be predominately derived from a manufactured source, not from the treated sewage effluent formerly discharged at the sewage treatment plant. Water sources that appear to contribute to contaminant migration toward the aquifer include underground pipeline leaks, intentional water discharges to unlined ditches, and infiltration of precipitation. Water infiltrating beneath the sewage treatment plant does not appear to significantly impact water quality in the aquifer beneath INTEC.

The sudden appearance of water in perched monitoring Well MW-15 in August 2004 is probably the result of leaks or discharges of fire/raw/potable water near CPP-603. Hydrogen and oxygen isotope ratios in the CPP-603 basin water are distinctly different from isotopic ratios observed in the perched water at Well MW-15, and therefore the basin water cannot be the source of the perched water observed in this well. The major ion composition of the perched water at Well MW-15 closely matches that of the fire/raw/potable water, which further supports this conclusion.

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Appendix A

Water Quality Trend Plots

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ENGINEERING DESIGN FILE

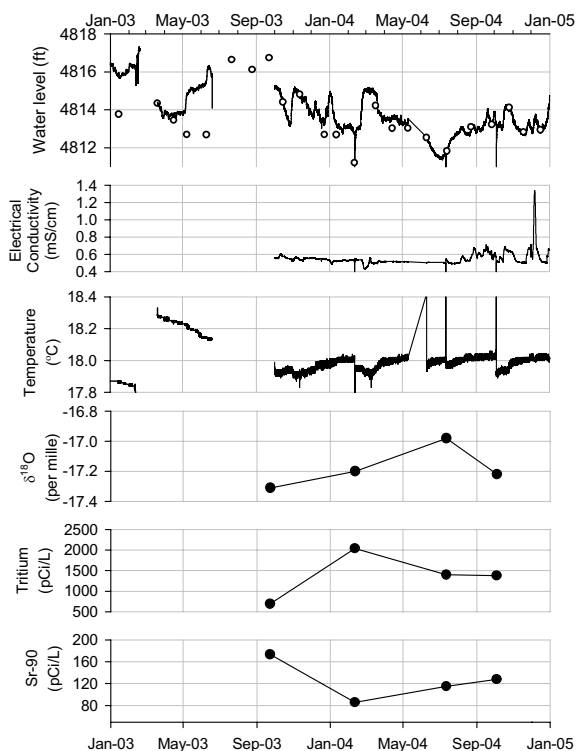
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Appendix A

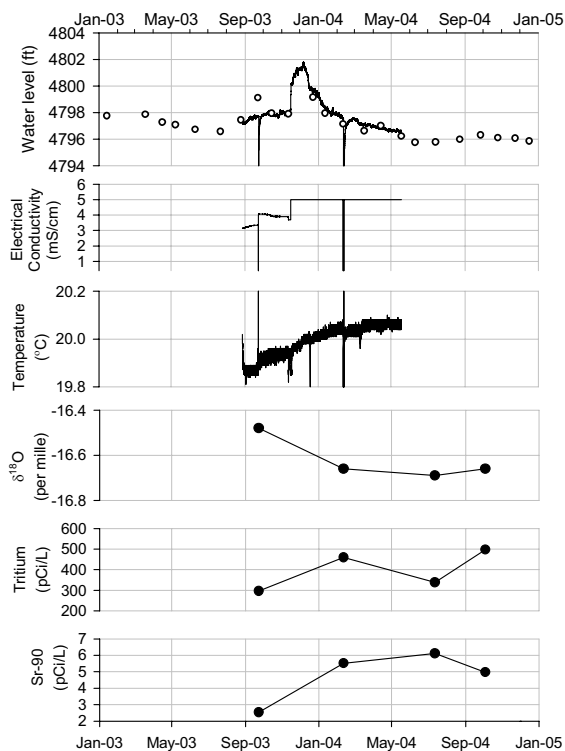
Water Quality Trend Plots

This appendix contains trend plots for perched water levels, downhole electrical conductivity and temperature, oxygen isotope ratios, and tritium and Sr-90 activities in perched water monitoring wells. Trend plots were only prepared for those monitoring wells equipped with automated water-level data loggers. These include perched monitoring Wells 33-2, 33-3, 33-4-1, 37-4, 55-06, MW-1-4, MW-2, MW-5-2, MW-10-2, MW-20-2, and MW-24. Water level and water quality data are shown for the period January 2003 through January 2005. Tritium activities in perched water were below detection limits at monitoring Wells 33-4-1 and MW-20-2; therefore, tritium trend plots were not generated for these wells. Electrical conductivity trends were not plotted for wells 55-06 and MW-20-2, because the downhole instruments installed at these locations were not equipped to record electrical conductivity.

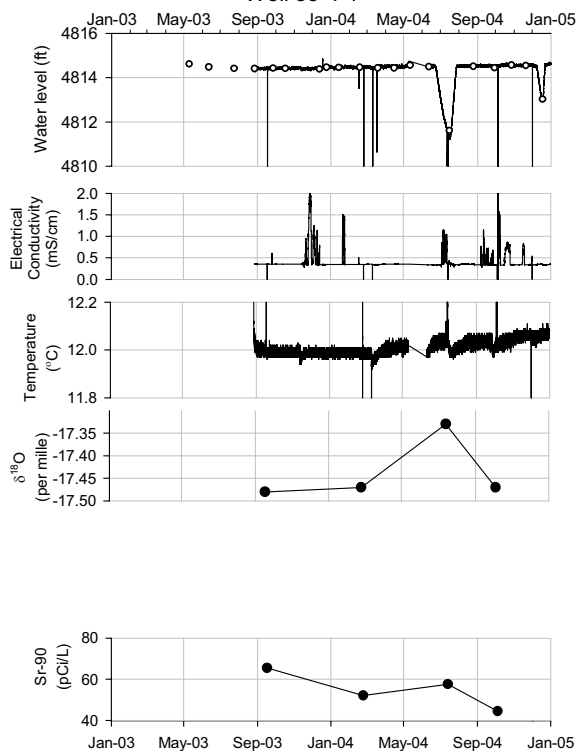
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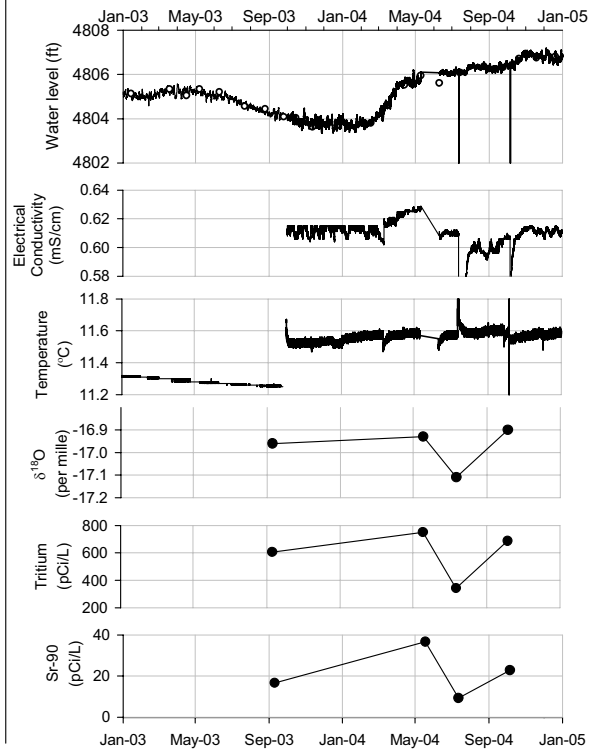
Well 33-3



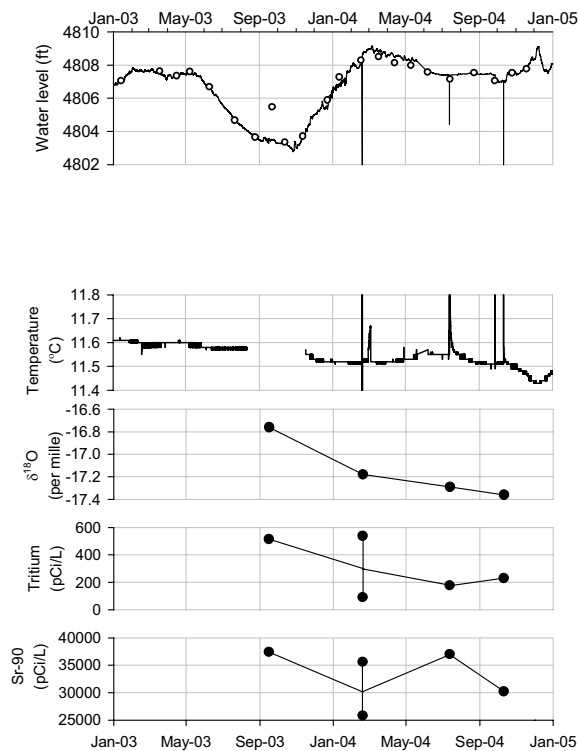
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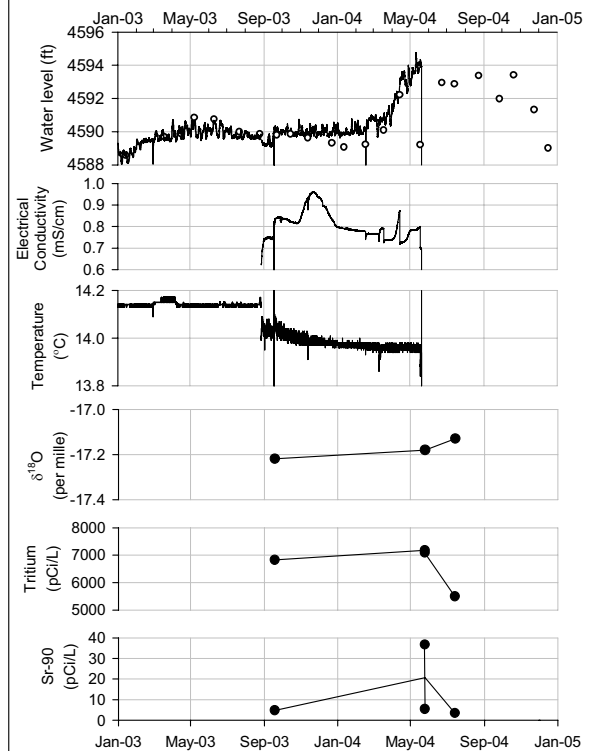
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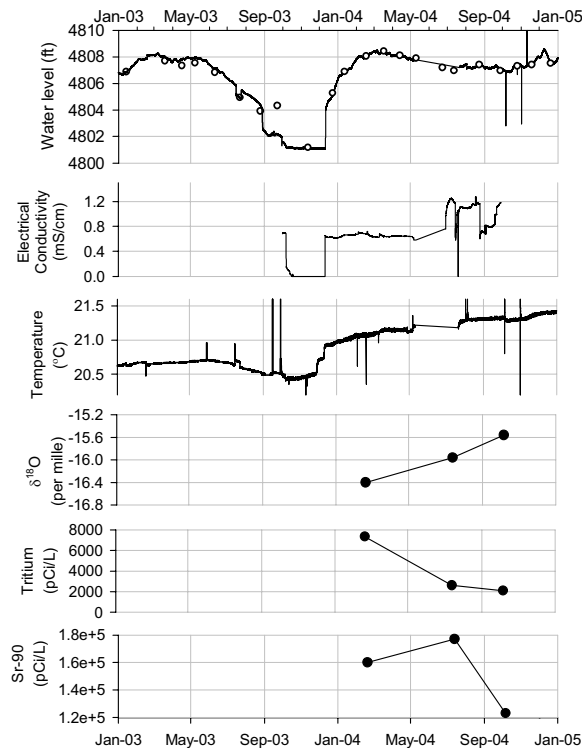
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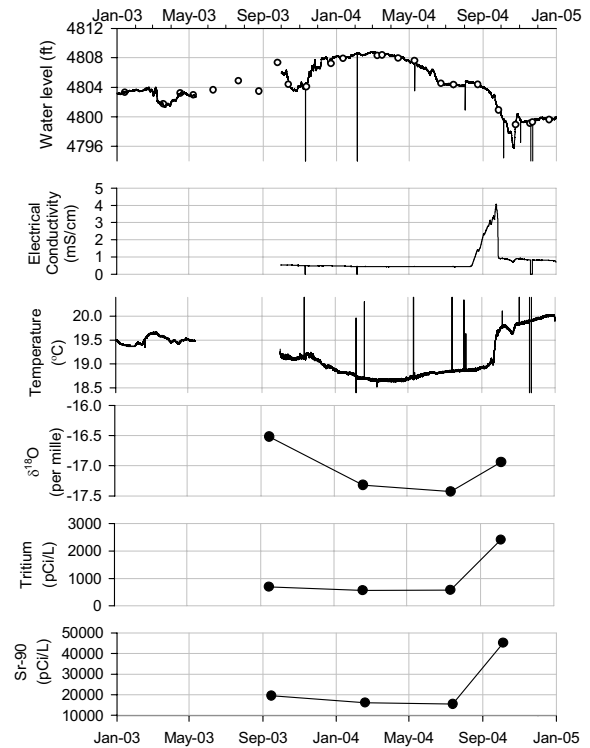
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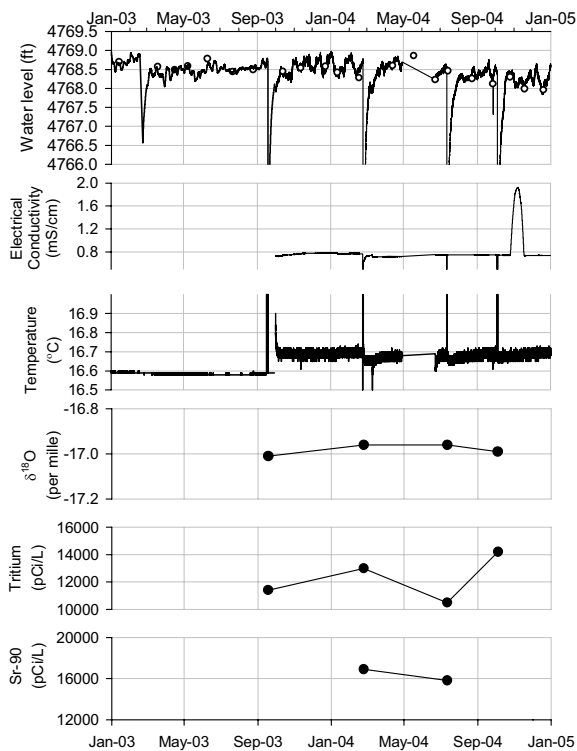
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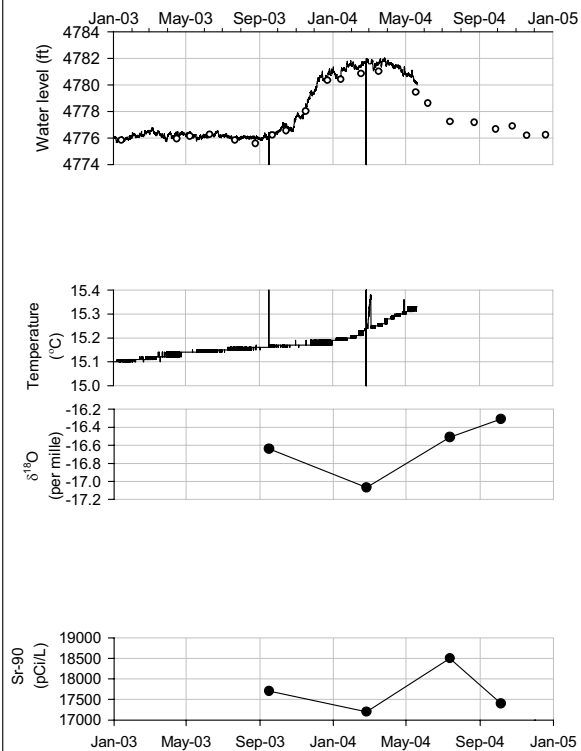
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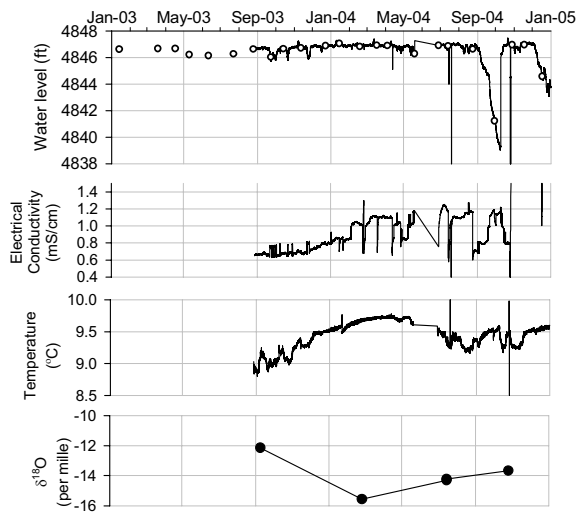
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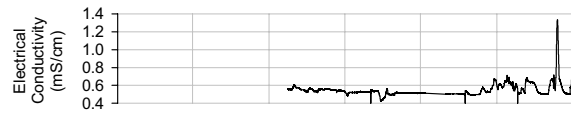


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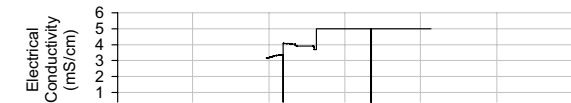
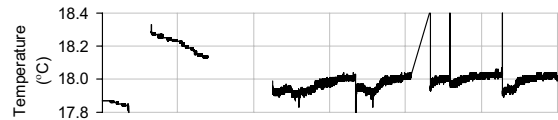


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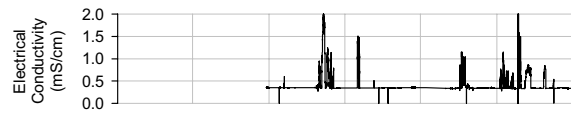
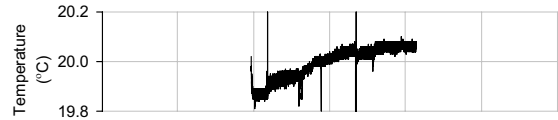




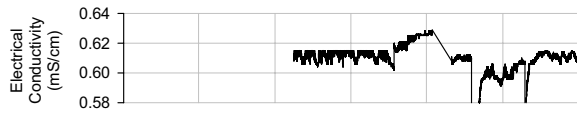
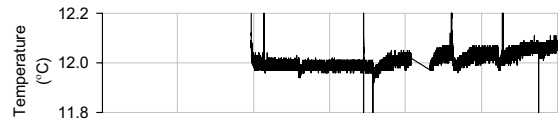
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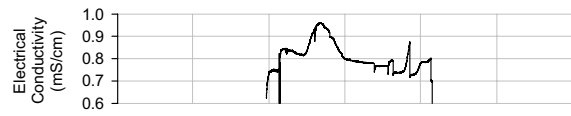
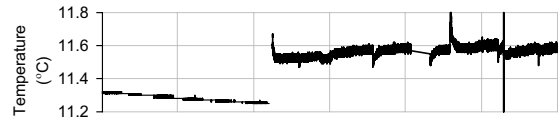
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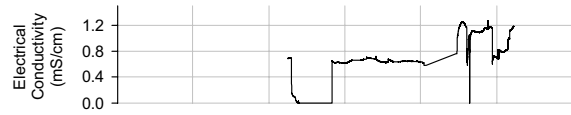
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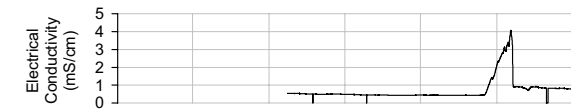
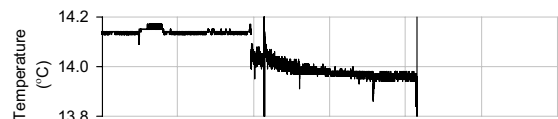
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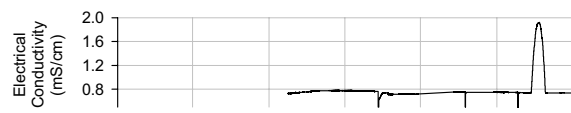
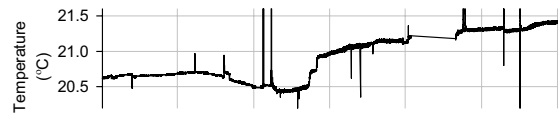
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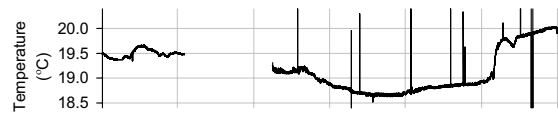
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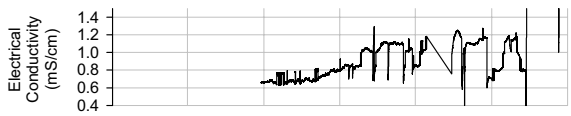
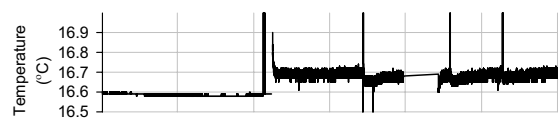
MW-2



MW-5-2



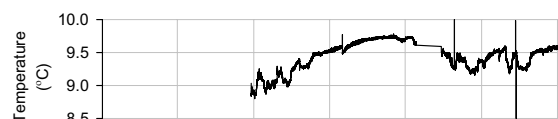
MW-10-2



MW-20-2



MW-24



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Appendix B

Analytical Methods and Results

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Appendix B

Analytical Methods and Results

This appendix includes the laboratory analytical results for the geochemical study. The complete results are provided on the attached CD. Samples were collected in September 2003, December 2003, February–May 2004, July 2004, and October 2004–November 2004. Details regarding sampling locations and analytical methods are included below. Note that alkalinity data are reported in units of mg/L as calcium carbonate.

B-1. Data Qualifier Flags

Data qualifier flags include data qualifiers assigned by the laboratory and qualifiers assigned subsequently during the data validation process. The data qualifier flags for inorganic and radiological results are defined as follows:

Inorganics Qualifier Flags

- B—Result is less than the contract-required reporting limit but greater than or equal to the instrument detection limit.
- E—Reported value was estimated because of the presence of interference.
- N—Spiked sample recovery was outside control limits.
- H—Flag applied by the laboratory to indicate that the holding time was exceeded.
- U—The analyte was not detected.
- UJ—The analyte was analyzed for, but not detected. The associated value is an estimate and may be inaccurate or imprecise.
- R—The accuracy of the data is so questionable that it is recommended that the data not be used. The “R” flag overrides all other applicable flags.
- *—Duplicate analysis was not within control limits.

Radiological Qualifier Flags

J—The associated value is estimated. The result may not be an accurate representation of the amount of activity actually present in the sample.

R—The accuracy of the data is so questionable that it is recommended that the data not be used. The “R” flag overrides all other applicable flags.

U—The radionuclide is not considered present in the sample (i.e., nondetect).

UJ—The radionuclide may or may not be present, and the result is considered highly questionable. The associated value is an estimate and may be inaccurate or imprecise. The result is considered a nondetect for project data interpretation purposes.

B-2. Notes on Ponded Water, Snow and Steam Condensate Sampling Locations

February steam condensate samples and surface water/snow samples were collected at multiple locations for this study. The original sample result tables only associate sample numbers with their general sampling locations—not the exact location a sample was collected. To avoid confusion, the following tables were generated to clarify where and when steam condensate and surface water/snow samples were collected, and to associate this information with the appropriate sample number. Table B-1 lists the ponded snowmelt and snow water sample numbers, along with sample collection dates and field location numbers (1-3) as noted in Logbook ER-131-2003. A map of these locations is presented in Figure 2-4 of this report.

Table B-2 presents the ponded rain water sample numbers sampled in October 2004 with their collection dates, station (sample location in the original result table), and field location letters (A–D) on Figure 2-4. The field location letters were created specifically for this report and are not listed in the logbook notes. A map of these locations is presented in Figure 2-4 of this report.

Table B-1. Summary of sample information for February 2004.

Sample Type	Sample Date	Field Location	Associated Sampling Number
Ponded water	2/25/2004	1	PWM35801LL
Ponded water	2/23/2004	1	PWM35801LL
Ponded water	2/23/2004	1	PWM35801N2
Ponded water	2/23/2004	1	PWM35801AN
Ponded water	2/23/2004	1	PWM35801AI
Ponded water	2/23/2004	1	PWM35801KJ
snow	2/23/2004	1	PWM361013A
Ponded water	2/25/2004	2	PWM35901LL
Ponded water	2/23/2004	2	PWM35901N2
Ponded water	2/23/2004	2	PWM359013A
Ponded water	2/23/2004	2	PWM35901AN
Ponded water	2/23/2004	2	PWM35901LL
Ponded water	2/23/2004	2	PWM35901AI
snow	2/23/2004	2	PWM362013A
Ponded water	2/25/2004	3	PWM36001LL
Ponded water	2/23/2004	3	PWM36001AN
Ponded water	2/23/2004	3	PWM36001LL
Ponded water	2/23/2004	3	PWM36001AI
Ponded water	2/23/2004	3	PWM36001N2
Ponded water	2/23/2004	3	PWM358013A
snow	2/23/2004	3	PWM363013A

Information source: Logbook ER-131-2003.

Table B-2. Summary of rainwater sample information for October 2004.

Sample Type	Sample Date	Result Station Name	Field Location	Associated Sampling Number
ponded rain water	10/28/2004	TF-DP	A	SWG020013A
ponded rain water	10/28/2004	BLR-AL	B	SWG021013A
ponded rain water	10/28/2004	MW-18	C	SWG022013A
ponded rain water	10/28/2004	MW-15	D	SWG023013A

Information source: Logbook ER-080-2004 and sample result table.

Table B-3 presents the steam condensate sampling numbers (February 2004) associated with their sampling dates and collection locations as noted in logbook ER-131-2003. A map of these locations is presented in Figure 2-4 of this report.

Table B-3. Summary of steam condensate sample information for February 2004.

Sample Type	Sample Date	Field Location	Associated Sampling Number
steam condensate - west CPP-606	2/25/2004	NA	PWM35701LL
steam condensate - west CPP-606	2/25/2004	NA	PWM35701AN
steam condensate - west CPP-606	2/25/2004	NA	PWM35701N2
steam condensate - west CPP-606	2/25/2004	NA	PWM35701AI
steam condensate - west CPP-606	2/25/2004	NA	PWM357013A
steam condensate - CPP-637	2/25/2004	NA	PWM356013A
steam condensate - CPP-637	2/25/2004	NA	PWM35601N2
steam condensate - CPP-637	2/25/2004	NA	PWM35601LL
steam condensate - CPP-637	2/25/2004	NA	PWM35601AI
steam condensate - CPP-637	2/25/2004	NA	PWM35601AN

Information source: Logbook ER-131-2003.

B-3. Hydrogen and Oxygen Isotope Ratio Analytical Methods and Reporting

The hydrogen and oxygen isotope analyses were performed by the USGS laboratory in Reston, VA. Since May 1, 1990, hydrogen-isotope-ratio analyses have been performed using a hydrogen equilibration technique (Coplen et al. 1991),^a rather than the zinc technique used prior to that date (Kendall and Coplen 1985). The hydrogen equilibration technique measures deuterium activity, whereas the zinc technique measures deuterium concentration. For the majority of the samples, the difference in reported isotopic compositions between the two techniques is not significant. However, in brines, the difference may be significant (Sofer and Gat 1972, 1975). Reported $\delta^2\text{H}$ values of activity are more positive than $\delta^2\text{H}$ values of concentration, and this difference is proportional to molalities of the major dissolved solids. Some examples of the differences between activity ratios and concentration ratios for $\delta^2\text{H}$ in 1 molal salt solutions are as follows (Horita et al. 1993). The concentrations of individual salts may be multiplied by molality to obtain adjustments to delta values based on concentration as follows:

a. Revesz, K and T. B. Coplen, 2003a, "Hydrogen isotope ratio analysis of water by gaseous hydrogen-water equilibration," Standard Operating Procedure (SOP) #1574, Techniques of the U.S. Geological Survey, in preparation.

Solution (1 molal)	$\delta^2\text{H}$ (activity) – $\delta^2\text{H}$ (conc.) (30 degrees C)
NaCl	+2.07 per mil
KCl	+2.42 per mil
CaCl ₂	+5.31 per mil
MgSO ₄	+1.12 per mil

Water samples are measured for $\delta^{18}\text{O}$ using the CO_2 equilibration technique of Epstein and Mayeda (1953), which has been automated.^b Therefore, both oxygen and hydrogen isotopic ratio measurements are reported as activities.

Oxygen and hydrogen isotopic results are reported in per mil relative to VSMOW (Vienna Standard Mean Ocean Water) and normalized (Coplen 1994) on scales such that the oxygen and hydrogen isotopic values of SLAP (Standard Light Antarctic Precipitation) are -55.5 per mil and -428 per mil, respectively. Oxygen isotopic results of a sample Z can be expressed relative to VPDB (Vienna Pee Dee belemnite) using the equation:

$$\delta^{18}\text{O} \text{ of Z relative to VPDB} = (0.97001 \text{ times } \delta^{18}\text{O} \text{ of Z relative to VSMOW}) - 29.99$$

The 2-sigma uncertainties of oxygen and hydrogen isotopic results are 0.2 per mil and 2 per mil, respectively, unless otherwise indicated. This means that if the same sample were resubmitted for isotopic analysis, the newly measured value would lie within the uncertainty bounds 95% of the time.

B-4. Nitrogen and Oxygen Isotope Ratio in Nitrate Analytical Methods and Reporting

The nitrogen and oxygen isotope analyses were performed by the Reston, VA. USGS laboratory. Nitrate samples are analyzed by bacterial conversion of nitrate to nitrous oxide and subsequent measurement on a continuous flow isotope ratio mass spectrometer (Sigman et al. 2001; Casciotti et al. 2002).^c

Nitrogen isotope ratios are reported in parts per thousand (per mil) relative to N_2 in air (Mariotti 1983). The nitrogen isotopic compositions of nitrogen-bearing internationally distributed isotopic reference materials, had they been analyzed in this laboratory with your samples, are:

N_2 in air	0 (exactly)
IAEA-NO-3 KNO ₃	+4.70
USGS32 KNO ₃	+180 (exactly)
USGS34 KNO ₃	-1.8
USGS35 NaNO ₃	+2.7

The 2-sigma uncertainty of nitrogen isotopic results is 0.5 per mil, unless otherwise indicated. This means that if the same sample were resubmitted for isotopic analysis, the newly measured value would lie within the uncertainty bounds 95% of the time.

b. Revesz, K. and T. B. Coplen, 2003b, "Oxygen isotope ratio analysis of water by gaseous carbon dioxide-water equilibration," Standard Operating Procedure (SOP) #489, Techniques of the U. S. Geological Survey, In preparation.

c. Revesz, K., and K. Casciotti, 2003, "Nitrogen and oxygen isotope ratio analysis of dissolved nitrate by the denitrifier method using continuous flow isotope ratio mass spectrometry," Standard Operation Procedure (SOP) #2900, Techniques of the U. S. Geological Survey, In preparation.

Oxygen isotope ratios are reported in per mil relative to VSMOW reference water and normalized on a scale such that SLAP reference water is -55.5 per mil (Coplen 1988, 1994). The oxygen isotopic compositions of oxygen-bearing internationally distributed isotopic reference materials, had they been analyzed in this laboratory with your samples, are:

VSMOW	water	0 (exactly)
SLAP	water	-55.5 (exactly)

IAEA-NO-3	KNO ₃	+25.6
USGS32	KNO ₃	+25.7
USGS34	KNO ₃	-27.9
USGS35	NaNO ₃	+57.5

The 2-sigma uncertainty of oxygen isotopic results of nitrates is 1.0 per mil unless otherwise indicated.

B-5. References

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